Protecting Puget Sound Watersheds from Agricultural Pollution Using a Progressive Manure Application Risk Management (ARM) System

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Quality Assurance Project Plan (QAPP)

Version 1.1

Previous Versions:
1.0

December 2010

Prepared by:
Whatcom Conservation District

Quality Assurance Project Plan

for

Project: Protecting Puget Sound Watersheds from Agricultural Pollution Using a Progressive Manure Application Risk Management (ARM) System

TITLE AND APPROVAL SHEET

Whatcom Conservation District

January 1, 2010

The following Quality Assurance Project Plan (QAPP) has been reviewed by the following officials and is herby recommended for approval.

____ Date:____________
George Boggs, Executive Director, Whatcom Conservation District

____ Date:____________
Nichole M. Embertson, Ph.D., Project Manager, Whatcom Conservation District

____ Date:____________
Jill Gable, Grant Program Office, Project Manager, EPA R10

____ Date:____________
Ginna Grepo-Grove, Quality Assurance Manager, EPA R10

____ Date:____________
Other

2. TABLE OF CONTENTS

Commented [NU2]: Many page numbers need to be updated (incorrect).

2.1. FIGURES

2.2. TABLES

3. DISTRIBUTION LIST

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4. PROJECT/TASK ORGANIZATION

The following section describes the individuals and organizations involved in the project and their primary roles.

4.1. Roles and Responsibilities

The Whatcom Conservation District is responsible for the development, implementation, and monitoring of the ARM project. The granting agency, US EPA Region 10, is responsible for the successful oversight and support for the ARM project. Responsibilities of each individual or agency are as follows.

4.1.1. Whatcom Conservation District

*Nichole M. Embertson***,** *Project Manager & Lead Scientist*, has an M.S. and Ph.D. in Animal Science with a specialty in Environmental Management and will act as Project Manager and lead scientist on the project for WCD. Nichole will be overseeing the scientific and collaborative tasks of the project including ARM creation and installment, sampling methodologies, statistical analysis, outreach, and maintenance of the approved QAPP.

Dawn Bekenyi, *Administrative Assistant*, will be responsible for financial and administrative record-keeping tasks associated with this proposal, as well as administration of the QA project plan.

George Boggs, *Executive Director*, has a B.S. in Agronomy and a J.D. in Law and will provide direct oversight to District staff and direct communication with regulatory agencies to ensure timely completion of the project tasks within budget.

Chris Clark, *Engineer in Training*, has a BS in Biological Systems Engineering with an emphasis in agricultural, soil and water engineering and will participate as a technical resource and engineer for the project.

*Andrew Phay***,** *IT Specialist*, has been the GIS Technician for the WCD for seven years, since completing a B.S. degree in Environmental Planning with a minor in GIS Studies and will be providing all GIS mapping services, new technology development, and database activities.

4.1.2. US EPA Region 10

Ginna Grepo-Grove, Regional Quality Assurance Manager

Jill Gable, Grant Program Officer

Karma Anderson, Project Technical Monitor

Krista Mendelman, Program Coordinator

4.1.3. Project Cohort

A Farmer Group and a Partner Cohort/Group will be assembled whose task will be to offer constructive input, feedback, and assessment of the system. Representatives from each of the following agencies have offered in-kind time to participate in various aspects of the project.

Local Dairy Farmers – Provide test farms and feedback on ARM tools and results.

Washington Dairy Federation – Help support efforts within the dairy community and provide contacts and communication outlets (i.e., meetings, newsletters, mails, etc.).

Washington Department of Agriculture (WSDA) – Work in close partnership with ARM enforcement and support.

Department of Ecology (~~DOE~~Ecology) – Provide feedback on the project data and tools.

Natural Resource Conservation Service (NRCS) – Work collaboratively to create and initiate new BMPs, incentive programs, and dissemination of ARM system.

Agriculture and Agri-Food Canada– Work with Shabtai Bittman on air quality monitoring and air quality risk section of ARM worksheet.

Western Washington University – Water sampling advisory and field sampling assistance.

Lummi Nation – Provide feedback on the assessment of the project.

Washington Conservation Commission – Partner with sister Districts to implement ARM system on a State-wide scale.

EPA – Work with our granting partners at EPA to integrate ARM system into applicable tools and programs.

Other advisory partners (offer feedback and support of project efforts): Portage Bay Shellfish Protection District, Ag Advisory Council, Farm Friends, Whatcom County Public Works, Drayton Harbor Shellfish Protection District Advisory Committee

4.1.4. Project Contractors

The project will utilize outside contractors for certain aspects of the project including laboratory analysis and web design. These individuals are identified within the QAPP (web designer TBA after bid process).

4.2. Project Organizational Chart

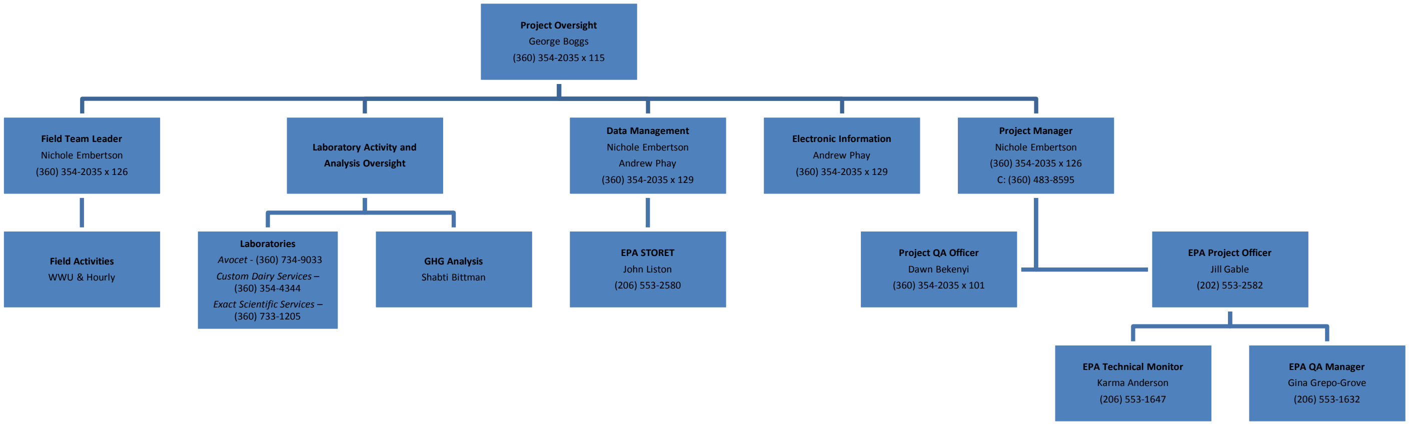

Figure 4.1. Project organizational chart showing primary individuals and organizations participating in the project.

5. PROBLEM DEFINITION/BACKGROUND

5.1. Area of Study

This project will be addressing two adjacent watersheds located in western Whatcom County, Washington: the Nooksack and the Strait of Georgia. These two watersheds encompass 1,687 mi^2 bordered by the Cascade Mountain Range to the east, Canada to the north, and the Pacific Ocean to the east. Within these two main watersheds are smaller watershed areas including the Lower Nooksack Sub-basin (Nooksack), as well as Drayton Harbor, Birch Bay, and Lummi Bay (Strait of Georgia). Each of these watersheds has surface waters that flow from inland areas to the marine, affecting the Puget Sound, as well as various resources, communities, and industries along the way. Collectively, the health of the two watersheds is under great pressure from land use changes and agricultural uses.

5.2. Problem Background

Of the 12 Washington State Puget Sound Districts, Whatcom County has the greatest concentration of dairy cows, with 53% of the total, or over 40,000 animals (2008), within its boundaries, most (~75%) of which are concentrated in the 310 mi^2 of the Nooksack and Strait of Georgia watersheds. Although the number of dairy farms in Whatcom has decrease by half in the last 10 years, the number of milk cows has only been reduced by about 30%, putting increased pressure on available land and water resources.

The combined Nooksack and Strait of Georgia watershed areas are under both land use change and environmental resource pollution strain. The primary resources and industries affected by these pressures are agriculture (primarily dairy), shellfish and salmonid fish populations, as well as the water and air quality that supports these industries and the populations that surround them.

Due to land use changes and population pressures, the Lower Nooksack Sub-basin has a heavily impacted floodplain, high nitrates in groundwater, elevated fecal coliform levels in surface waters, and poor riparian conditions throughout the Nooksack River and most of its tributaries. Department of Ecology’s ~~(DOE)~~ current 303(d) list of impaired waters shows that there are 34 stream and river segments in the watershed that are above acceptable limits for, among other things, fecal coliform. The ~~DOE~~Ecology Nooksack River Watershed TMDL (Hood, 2002) plan lists the improper application of manure to agricultural fields as a potential significant source of fecal coliform to the watershed. The discharge of fecal coliform into local harbors and bays has led to a significant history of shellfish bed closures and reopenings, which has had a detrimental effect to Tribes and commercial harvesters.

Poor water quality, coupled with the loss of stream habitat, has contributed to the noticeable decrease in annual salmon populations returning to the watershed (Ruckelshaus et al., 2002). This impacts Tribal communities as well as local industries, and threatens the future health of the salmon population in the area. Additionally, compared to other rivers in the Puget Sound region, the Nooksack River near its mouth at Portage Bay has among the highest levels of nitrogen, phosphorous, and suspended solids, which affects both upstream fish and shellfish populations in adjacent marine waters.

In addition to water quality, air quality is also adversely impacted by growth and improper land use. Urbanization leads to an increase in fuel use and urban emissions, which when combined with natural VOC production from vegetation and agricultural ammonia emissions (which are not currently addressed nor regulated), can increase the production of smog and fine particulate matter ($PM_{2.5}$), respectively. This fine PM can adversely affect human health and deposit via rain or dry deposition on inland waterways and on the Sound, increasing nutrient loads and decreasing water quality. A reduction in agricultural ammonia production, up to half of which can come from field manure application (Pinder et al., 2004; Rotz, 2004), may aid in reducing smog and PM deposition within the Puget Sound airshed. Urbanization can also increase greenhouse gas production and subsequent climate change issues in the region via the conversion of productive agricultural and forested lands to impervious urban surfaces, which decreases vegetative carbon sequestration. Climate change coupled with population growth has put a strain on already scarce and diminishing water resources available for municipal and agriculture irrigation use in the watershed.

In Whatcom County, as in many other counties in the State, impacted and poorly managed agriculture (in particular, manure application) has repeatedly been advanced as a leading contributor to air and water pollution in watersheds. Therefore, the most productive way to address many of the water and air pollution issues within the watershed, and contribute to the larger interconnected effort of protection of the watershed, is to target the application of manure to farm fields. Improper application of manure can lead to runoff, which can adversely impact water bodies with nutrients and pathogens. Since dairies are the largest producers of manure and manure application in the watershed, improvements in field application methods and timing are necessary in order to protect important watershed and air resources from further negative impacts.

However, current guidelines do not promote better application practices, and in fact, threaten the health of the Sound even further by fostering application under risky conditions and times of the year (October and February) without proper assessment of weather or field conditions. Currently, the ceasing of manure application in Whatcom in the fall is Oct. 15th in the floodplain, and Oct. 31st everywhere else; and the start date of applic~~i~~ation in the spring is T-Sum200 (200 cumulative celcius temperature units after Jan 1) or February 15, regardless of current ~~fieldd~~field and weather conditions. The dates are estimated values chosen to coincide with the start of flood season and plant growth, respectively, but in a changing climate and impacted resources concerns, are not always accurate or ideal. These application dates do not require farmers to assess their unique field conditions and practices prior to application; prevents application at times when it may be more faviorable; do not promote planning of dry season application; and they do not prevent farmers from applying during unfavorable conditions, contributing to both surface and groundwater pollution. Instead, they encourage application in the fall when uptake is diminishing and rainfall and leaching potential is high (Paul and Zebarth, 1997; Beckwith et al., 1998; Almasri and Kaluarachchi, 2004; Hepperly et la., 2009), and allows spring application on a date that may encourage application during high precipitation events and/or when soil moisture is high, which can contribute to runoff (King and Tobert, 2007). Additionally, an increase in dry season (June-Sept) episodic air pollution events may be partially contributed by increased ammonia from manure application during hot, dry weather conditions (Harper et al., 2009). This is an issue that has not yet been addressed in Whatcom.

It is the objective of this project to create an Application Risk Management (ARM) system that will help farmers reduce their risk of manure induced pollution within the watershed (see Section 6 for more detail of system components). The ARM system would supplant the current ridged application dates listed above and instate a more fine-tuned approach to manure application timing following crop agronomic rates (based on predicted and historical crop yield, and nutrient guidelines obtained from Washington State Fertilizer Guides issued WSU Cooperative Extension), current field conditions (observed), and meteorological parameters (observed and forecast) year-round. Along with a detailed field risk analysis and informational tools, the removal of rigid dates (Whatcom County Manure Ordinance 98-074, Chapter 16.28 rules and guidelines will still apply) inserts a level of flexibility that allows manure application to be done in a *more* responsible manner, while also allowing adjustment for the unpredictability of seasonal weather conditions and a changing climate. This will help prevent application in risky times and support application at times when it is appropriate and poses the least threat to resources.

The ARM system can be successful in contributing to the goals of the dairy industry, WRIA 1, as well as EPA national goals for Puget Sound, by improving the management and health of 37,000 acres of impacted farmland, 350 miles of impaired waterways, and 7,000 acres of shellfish growing areas. It will also address the priorities of the Puget Sound Action Agenda by targeting a source of water pollution in the watershed and protecting it from future pollution with education and good management tools. Lastly, the holistic approach of looking at air and water together addresses EPA's clean air and clean water priorities by eliminating sources of airborne deposition of nutrients (nitrogen) on waterways.

Since other dairy producing districts in the Puget Sound share our same environmental issues, this system will be widely shared with others to decrease the impacts of agricultural pollution beyond Whatcom County. It is our intention to adapt and share this system with other Conservation Districts and livestock management agencies in Washington State and the Region, as well as our partners in Canada, all who share some or all of the same resource concerns as we do.

5.3. Project Objectives

1. Conduct a series of land surveys to identify areas within the watershed that are at high risk for ground and surface water pollution, as well as classify low risk areas that are best suited for agricultural land use.
2. Send out a statistically assessable survey to dairy producers to gain a better understanding of current environmental based practices, constraints to BMP adoption, knowledge base, and effective communication routes.
3. Develop and scientifically evaluate an interactive Application Risk Management (ARM) system that minimizes nutrient and pathogen pollution events to air, surface and ground water using a combination of field risk analysis, application field assessment, education, risk alert tools, and accountability.
4. Collaborate with project partners and farmer groups to open discussion and test ARM tools.
5. Assess current NRCS vegetative practices and manure application setback guidelines for seasonal effectiveness at managing potential runoff from fields.
6. Develop educational and informational materials that will be available to all producers and custom manure applicators including a workshop, webpage, risk alerts, newsletter, and email/fax information system. These materials will help manure applicators learn about the program, get help, and keep informed on times when application is optimal or prohibited.

7. Integrate the ARM system into planning software and Nutrient Management Plans at a County and State wide level.

The long-term outcome of this project is the implementation of a more comprehensive and effective manure application management system that will reduce runoff and air pollution events, decrease the fecal coliform and nutrient loading into the Nooksack and Strait of Georgia Watersheds to increase the vitality of freshwater fish and marine shellfish areas, increase surface and groundwater quality, and improve air resources for the community. Additionally, by giving farmers a more active and responsible role in the management of their land, we hope to reinvigorate the sense of environmental stewardship that was once prevalent in this area and reconnect farming to the community.

6. PROJECT DESCRIPTION

This study aims to develop an innovative Application Risk Management (ARM) system that targets the transport of manure nutrients and fecal coliform to environmental resources such as surface water, groundwater, and air, and increases agronomic application rates and accountability. The study will be conducted in 4 phases, 1) Assessment, 2) Development, 3) Implementation and Monitoring, and 4) Evaluation, Adaptation, and Outreach over four years.

The activities listed in each phase below are summaries and not necessarily a detailed assessment of how the activities will be conducted or tools created. The character of those processes is not appropriate for a QAPP. The QAPP contains detailed information on the methods and QA for field data collection only.

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The QAPP will be revised and amended annually or as needed based on field results, project updates, developments, or other factors that may significantly change the project plan. All addendums will be vetted through the proper review and update process.

6.1. Phase 1: Assessment

Phase 1 is the characterization and assessment of the watershed as it relates to agricultural practices and potential environmental impacts with GIS mapping utilizing soil type, critical areas inventories, groundwater recharge rates, land use inventories, and any current environmental data available that will help make an assessment (groundwater sampling data, stream monitoring data, etc). Using a risk rating system based on 15+ different soil and field characteristics including soil type, permeability rate, seasonal high water table, distance to surface water, slope, hydrologic group, available water holding capacity, drainage rate, flooding potential, ponding potential, compaction potential, runoff rate, aquifer recharge rate, wetlands present, vegetative buffer type and width, and crop type (additional characteristics may be added as the project progresses and the system is tested), separate watershed and field maps will be created for runoff, leaching, and air pollution risk potential using GIS (ESRI, ArcMap) and visual field analysis. Risk factors (low, low-medium, medium, medium-high, and high) for the resources assessed will be based on current knowledge and information, and improved upon based on the results obtained by this research project, so that they are protective of the *specific* resource they are evaluating. By working with project cohorts on risk factor ranking, the process will ensure that all risk factors and evaluations are comprehensive and addressed in a scientifically responsible manner.

This analysis will be ~~sued~~ used to characterize the County and identify "hot spots" (an area of the County that is at a high risk for either runoff or leaching potential, currently has high nitrates in the groundwater, or is in an area that has high measured nutrient/pathogens in runoff and therefore may require more substantial management of nutrient sources or land use) within the watershed that will benefit most from a targeted approach for risk management. This land survey will aid in Whatcom County land use planning by locating areas that are best suited for agriculture and help farmers make better land use decisions on crop selection, application timing, and manure application technologies. This same process will be used on a micro scale with individual farms to assess the risk level associated with manure application to specific farm fields. The risk rating system will be scientifically tested via field measures and revised continuously throughout the project as new results and assessments are obtained.

To better identify the most effective modes of communication with landowners, producer preferences, appealing incentives, knowledge base, and current practices, an anonymous survey will be sent out (mail and web based) to all dairy producers in Whatcom County. The survey is designed to give descriptive results and will be statistically analyzed via ANOVA and chi-square for preferences and relationships to give us an idea of information target areas and delivery systems.

Phase 1 Deliverables

- Land survey and risk rating index for watersheds.
- Individual land risk evaluations for project farms as they are enrolled in ARM.
- Survey results of dairy producers to gain a better understanding of current practices, constraints to mitigation, preferences for manure management, and knowledge base.

6.2. Phase 2: Development

Phase 2 is the development of the Application Risk Management (ARM) System components to address both water and air quality impacts associated with manure application. The ARM tool is based on two main assessments, the individual farm field risk evaluation (presented in Section 6.2), and the use of a web-based ARM worksheet designed to assist a producer in assessing the risk of various parameters (i.e., weather, field conditions, etc.) with manure application and mitigating against pollution potential.

Prior to application of manure to any field, any time of the year, a producer will have to complete the ARM worksheet, which will evaluate runoff, leaching, and volatilization potential and provide feedback for proper application techniques. The worksheet will evaluate pollution potential (i.e., distance to resources, emissions, groundwater recharge, etc.), current field conditions (i.e., ponding/flooding, frozen ground, soil moisture, water table depth, vegetation density and height, buffers, etc.), application method, and current and forecasted weather conditions. All of these parameters, along with crop, soil type and nutrient analysis, will be entered into an interactive worksheet, which will provide feedback on individual parameters and calculate a pollution risk rating for runoff, leaching and ammonia emission, as well as a maximum recommended agronomic application rate. If conditions are not optimal for application (i.e. water table <24 inches, rain event >0.5 inches in 3 day forecast, low crop uptake, etc.), the system would tell producers to stop and wait to apply. The thresholds values for what is considered "optimal" will be based on values obtained from scientific literature and/or calculations supported by both modeled, observed, and field proven values for each of the criteria, as well as comprehensive parameter definitions and feedback responses. The worksheet will be created based on best available values obtained from scientific literature for the region, and revised as field data is collected (field data will be collected in Phase 3 of the project). All of these functions will be integrated into a user-friendly, web-based worksheet that will give automatic feedback on input values and log the data for analysis. The worksheet will allow producers to responsibly evaluate each of their fields on a seasonal basis and only apply an appropriate amount of manure to fields that are at low risk for environmental pollution. Once developed, the final worksheet and specifics will be included as an addendum document to the QAPP.

Commented [NU4]: Will the QAPP Addendum include all formulas and an explanation of all assumptions?

To ensure producers have accurately performed the calculations to evaluate their application risks, an accountability system will be implemented where all worksheets will have to be submitted to WCD prior to application for approval. For the life of the project, all worksheets will be visually assessed by project personal. As the project progresses, a system will be created for approval that provides a level of scrutiny, while also being efficient. Methods to be tested include an automated logging, tracking, and alert system that will trigger an alarm for higher level risk factors for further scrutiny; an added visual appraisal of all early and late season applications; a visual appraisal for one year of all new ARM users and automated for compliant veterans; or other techniques that will be determined through the project process. This level of "supervision" is vital in order to protect against potential environmental impacts. In order to remain in the ARM program, producers must follow all guidelines and recommendations set forth. If a producer deviates from the system, and applies manure outside of their DNMP protocols, a penalty protocol will be instituted by the appropriate regulatory agency (not WCD) and/or their application flexibility will be revoked. Currently, the regulatory agency enforcing on dairy operation activities is WSDA. The penalty details and enforcement capabilities of WSDA need to be outlined with regulatory agency cohorts as the project progresses.

In addition to the ARM worksheet, new risk management tools will be developed to raise awareness of risk factors and educate farmers. These tools include application alerts (email, web, and/or text) based on current weather events; a webpage with local forecasts, worksheet Q&A, application techniques, vegetative buffer affectively and maintenance guide, and others, to provide farmers with information relevant to application and the ARM system; and lastly, an self-update system for farmers to update their NMP on an on-going basis to adjust application levels as needed to meet agronomic rates (agronomic rate will be assessed using historical and actual data for soil and crop values, as well as other factors such as soil temperature and predicted conversion of manureal N to a plant available form as it correlates to plant uptake).

To guarantee that we are creating a useful, efficient product, a two tiered technical workgroup will be assembled consisting of a farmer panel and cohort workgroup (see Section 4.1.3). The group will be anchored by progressive and cooperative dairy producers who are willing to utilize and offer constructive criticism of the ARM system and communicate to fellow dairymen. In addition to their individual contributions to project components, input will also be requested of the project cohort to make sure we are meeting common goals and collaborating in a productive manner. Meetings will be held bi-annually for farmer panel and annually for partners (more frequent meetings may be scheduled as necessary based on cohort request). Project updates, reports, and/or data dissemination to the cohort will be conducted on an on-going basis as project deliverables are met.

Phase 2 Deliverables

- ARM Worksheet.
- An accountability system including an emergency response plan and monitoring and enforcement plan.
- Development of ARM tools: application alerts, webpage, self-update system.
- Assembly and meeting of workgroups including the farmer panel and cohort group.

6.3. Phase 3: Implementation and Monitoring

The ARM system will be installed, monitored, and evaluated at dairies within the target watersheds starting in 2011 until 2014. The first year, we will test the ARM system on 5 fields on dairy farms that have already given their commitment to participate in the project and provide feedback. We kept this number to 5 the first year to ensure we can provide a high level of observation, management, guidance, and sample monitoring appraisal in the infancy of the system. Each successive year, we will add new test farms/fields to the project throughout both watersheds (see Section 10.2 for sample strategy). Farm fields will vary in risk rating and location within the watershed, illustrating the different characteristics of the watershed areas. Every farm that participates in the study will have a Nutrient Management Plan update, as well as detailed GIS risk mapping of fields (see Section 6.1), water systems, and identification of sampling locations.

Commented [NU5]: More discussion likely between EPA and WCD regarding the scope/pace of adding additional fields…

To measure the effectiveness of the ARM system, concurrent soil, surface water, soil water, forage, manure, and air quality testing will be conducted on selected test fields throughout the year (see Table 6.1 for specific analysis). All sample data will be analyzed using statistical models to evaluate significance (alpha level of 0.05) within test sites and between test and control sites (see Section 10). The information in this QAPP document details the sample procedures and project data management.

Table 6.1. Summary of analyses for each medium sampled

Surface Water	Soil Water	Air	Soil	Manure	Forage	Meteorological
Laboratory						
Fecal coliform (FC), total-N, total kjeldahl nitrogen (TKN), nitrate, total-P	FC, total-N, TKN, nitrate, total-P	Nitrous oxide, methane, carbon dioxide	Electrical conductivity (EC), organic matter (OM), FC, total N, nitrate, total P, pH	EC, OM, C:N, FC, total N, ammonium, nitrate, total P, pH	Dry matter (DM), crude protein (CP), total-P, nitrate	-
Field Equipment						
Dissolved oxygen, pH, temperature, conductivity, nitrate, ammonium	Dissolved oxygen, pH, temperature, conductivity, nitrate, ammonium	Ammonia	Soil moisture, soil temperature	-	-	Temp, RH, wind speed, wind direction, pressure, altitude, dewpoint, wet bulb temp, precipitation

In conjunction, surface water quality data from current ~~DOE~~Ecology and WRIA 1 stationary monitoring sites will be assessed to provide information on current and historical temperature, FC, and DO levels (as applicable), variability, and pollution spikes in specific watersheds to help us locate problem areas and times of the year.

Phase 3 Deliverables

- Identification of test farms and installation of ARM system.
- Monitoring of the ARM system tools via field data (surface water, soil water, sir, soil, manure, forage, and meteorological) and producer use feedback.

6.4. Phase 4: Evaluation, Adaptation, and Outreach

Evaluation and revision of the ARM system will be conducted as results are obtained and input is received from producers (users) and project cohort (evaluators). Evaluation and effectiveness of the ARM tools will be based on the results of the measured field data, which will compare the ARM system application strategy against the current paradigm. Success will be evaluated on the ability of the ARM system to reduce potential pollution events and increase awareness of pollution pathways. Additionally, feedback on the ease of use, level of information, and overall usefulness of producer tools will be collected and used to modify tools to make them better. The evaluation and adaptation process will ensure that the system and its tools are user friendly, comprehensive, and successful at achieving the desired watershed protection goals.

Once evaluated and proofed scientifically, all Dairy Nutrient Management Plans created or updated by WCD will include the ARM system evaluation and access to tools. In addition, cost-share incentives will be explored with NRCS to identify sources of funding for farmers implementing the ARM system with more rigorous conservation practices and application technologies. Additionally, guidelines for manure application dates, setbacks, and restrictions will be proposed for review and revision to reflect our findings and more stringent guidelines. This endeavor will need to be explored with the project cohort. Our goal is to adapt the ARM system to all forms of agriculture that apply manure including berry and crop farmers, small farms, hobby farms, grazing operations, mitigation projects, and other livestock (poultry, beef, swine). This adaptation to other sectors of agriculture and other regions will be conducted in the last phase of the project.

A public outreach effort will be initiated to inform and gain support from the public. A workshop, web link, quarterly newsletter, email/fax/text alert system, and development of new technologies will aid in keeping producers and the community involved and informed on the systems progress and benefits.

In addition to quarterly reports, the final report will evaluate the system with scientific basis and determine its sustainability and effectiveness at achieving a permanent reduction of pollutants contributed by manure application to agricultural fields.

Phase 4 Deliverables

- Continuous evaluation and adaptation of ARM system based on project results and user feedback.
- Explore cost share incentives, revise manure application dates, explore legislation to incentivize the ARM system, and adapt ARM to include all forms of agriculture that utilize grazing or manure application practices.

- Outreach activities including a newsletter, email list, and workshop to educate users about the ARM system and related environmental issues.
- Quarterly reporting throughout project and final report at conclusion.

6.5. Study Area

The following map shows the area of study for the project. Specific study sites are not identified on this map due to confidentiality issues; however, targeted areas are circled in blue.

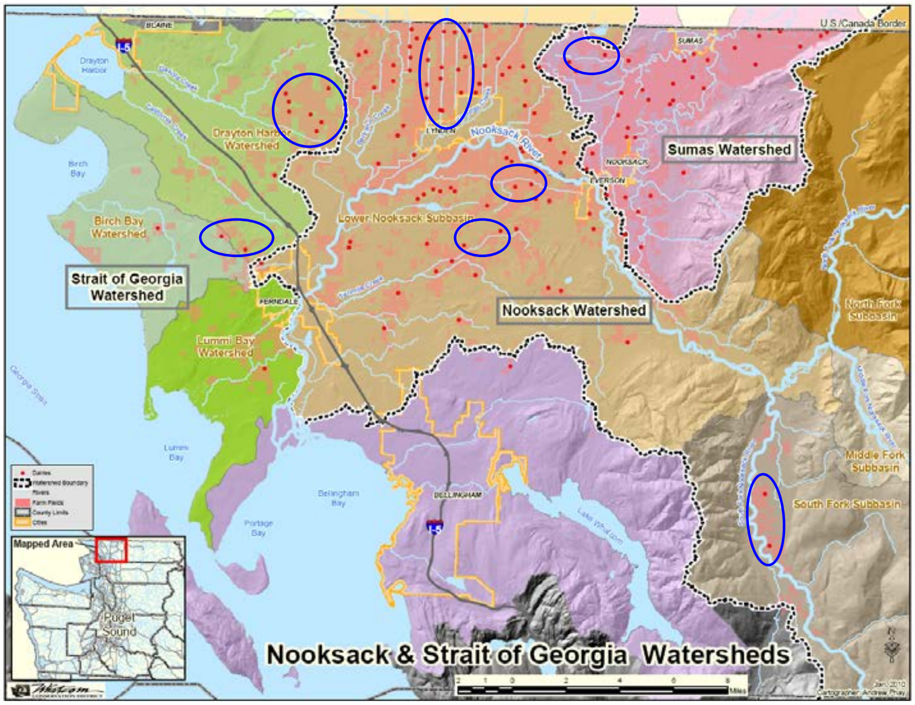

Figure 6.1. Map of study area. Test farms will be located in the Strait of Georgia and Nooksack Watersheds. Red dots depict dairies and pink areas represent the land base associated with those dairies. Blue circles represent areas where test farms are proposed over the course of the study.

6.6. Project Timeline

The following table shows the timeline of major tasks and deliverables to be completed during the project time frame. The dates listed are approximate and may vary depending on other task completion dates, partner availability, weather, and unforeseen circumstances. Project deadlines will adhere to listed dates as best as possible.

Table 6.2. Project timeline

Task	Action	Timeline*
Year 1		

Project start date	Start	July 1, 2010
Equipment purchase	Start	August 1, 2010 - Open
Enroll test farms (*Year 1*)	Start	August 15, 2010
QAPP Development and submittal	Due	October 1, 2010
QAPP review and revise	Start	October 1, 2010 - Open
ARM survey assessment maps	Start	November 1, 2010 - Open
Quarterly Newsletter (#1)	Due	December 15, 2010
Bi-annual reporting (NA)	Due	January 1, 2011
Develop and send out survey	Due	January 31, 2011
ARM Worksheet development	Start	February 1, 2011 - Open
ARM tools development	Start	February 1, 2011 - Open
Develop emergency response plan	Due	February 1, 2011
Quarterly Newsletter (#2)	Due	February 10, 2011
Farmer Panel Group Meeting	Due	February 15, 2011
Partner Group Meeting	Due	February 20, 2011
Field equipment installation	Start	March 1, 2011
Begin field sampling	Start	March 1, 2011
Identify and enroll test farms (*Year 2*)	Due	May 1, 2011
Quarterly Newsletter (#3)	Due	June 1, 2011
Year 2		
Bi-annual reporting	Due	July 1, 2011
Partner Group Meeting	Due	August 1, 2011
Quarterly Newsletter (#4)	Due	September 1, 2011
Quarterly Newsletter (#5)	Due	December 1, 2011
Farmer Panel Group Meeting	Due	December 15, 2011
Bi-annual reporting	Due	January 1, 2012
Quarterly Newsletter (#6)	Due	March 1, 2012
Enroll test farms (*Year 3*)	Due	May 1, 2012
Quarterly Newsletter (#7)	Due	June 1, 2012
Year 3		
Bi-annual reporting	Due	July 1, 2012
Partner Group Meeting	Due	August 1, 2012
Quarterly Newsletter (#8)	Due	September 1, 2012
Quarterly Newsletter (#9)	Due	December 1, 2012
Farmer Panel Group Meeting	Due	December 15, 2012
Bi-annual reporting	Due	January 1, 2013
Quarterly Newsletter (#10)	Due	March 1, 2013
Enroll test farms (*Year 4*)	Due	May 1, 2012
Quarterly Newsletter (#11)	Due	June 1, 2013
Year 4		
Bi-annual reporting	Due	July 1, 2013
Partner Group Meeting	Due	August 1, 2012
Quarterly Newsletter (#12)	Due	September 1, 2013
Quarterly Newsletter (#13)	Due	December 1, 2013
Farmer Panel Group Meeting	Due	December 15, 2013
Bi-annual reporting	Due	January 1, 2014
Finalize and release educational materials	Due	February 1, 2014
Workshop on ARM system	Due	February 1, 2014
Outreach ARM to all partner agencies	Due	February 1, 2014
Quarterly Newsletter (#14)	Due	March 1, 2014

Final Report	Due	July 1, 2014

*Dates and activity timelines are subject to change

7. QUALITY OBJECTIVES AND CRITERIA FOR MEASUREMENT DATA

The EPA outlines a Data Quality Objectives (DQO) process for addressing the specifications needed to support the qualitative and quantitative components of the project as well as the performance or acceptance criteria of the study design. It must be noted that no data are free of error and that some level of uncertainty must be accepted.

This area of the QAPP relates to the data (surface water, soil water, soil, manure, forage, and air) that will be collected in the field from test farms. A more detailed breakdown of the acceptance criteria and frequency of QC measurements for both field and lab parameters are located in Section 14.

7.1. Data Quality Objectives

Data Quality Objectives are qualitative and quantitative statements derived from the DQO process outlined in the EPA document: *Guidance for Data Quality Objective Process* (EPA QA/G4). This process outlines the monitoring objectives, defines the appropriate type of data to be collected, and specifies the tolerable levels of decision errors for the monitoring program.

The objective of this study is to obtain data that will aid in the characterization and assessment of the environmental impact of manure application to farm fields in relation to parameters set forth by our risk assessment (Section 6.1). More specifically, the data quality objectives are to: ensure that the parameters measured during this study will adequately describe nutrient cycling in the system at levels necessary to understand the processes taking place; to insure that sample results are representative of the target watershed at the time of sampling and that the data produced during this study are accurate; and lastly, to reduce the uncertainty associated with manure applied nutrient cycling in the environment (water, air, soil). In order to accomplish this, we have determined that environmental and meteorological data need to be collected based on appropriate sampling and analysis methods. Data collected will be used to establish thresholds for Worksheet assessment parameters, as well as for general system characterization purposes.

7.2. Measurement Performance and Acceptance Criteria

Measurement, performance, and acceptance criteria help maintain data within an acceptable range of uncertainty. In general, we expect a normal distribution for measurement error with decision error limits set at 5% (alpha = 0.05). Additionally, measurement imprecision is established at a 10% coefficient of variation (CV). The quality of the data will be evaluated and controlled to make sure it is maintained within the established measurement criteria listed using principle indicators of precision, bias, accuracy, representativeness, comparability, completeness, and sensitivity. Each of these indicators is detailed below (definitions are adapted from EPA definitions outlined in *EPA QA/G-5*).

7.2.1. Precision

Precision is a measure of mutual agreement among replicated (or between duplicate) or collocated sample measurements of the same analyte, which is represented by the coefficient of variation (CV = 10%). The closer the numerical values of the measurements are to each other, the more precise the measurement. Precision is determined through calculation of analytical and/or total measurement error. To increase precision and reduce variability between measurements, we will follow accepted/approved methods which are documented by standard operating procedures (SOP) for instrumentation placement and use, sample collection, sample handling, and analysis. The same analytical instrumentation and methods will be used to make repeated analysis on duplicate samples to ensure precision. Additionally, quality control and duplicate or split field samples will be taken and submitted for precision of sampling handling, preservation, storage, and analytical measurements. Laboratory analysis will be verified for precision by submitting blind replicates to the same laboratory. If the replicate falls outside of the acceptable range of 30% difference between samples, samples will be resubmitted (if duplicates are held in storage) or retaken (If applicable). Any identified areas of sample attainment that have variation outside of the acceptable limits will be reassessed and adapted to reduce variability. See table 7.1 for field equipment accuracy criteria which will meet the project DQOs.

Commented [NU6]: This is derived as a result of 3sigma of the 10% CV right?

Commented [NU7]: Will also need to insert the lab criteria (I have included a sample for this)

7.2.2. Bias

Bias is the systematic or persistent distortion of a measurement process that consistently causes error in one direction. To avoid sample bias from sample attainment, processing, or analysis, reference methods (Table 7.2) and SOPs will be followed. To avoid sample bias from analytical field equipment, equipment will be calibrated on a regular basis following manufacture guidelines. To assess laboratory bias, duplicate samples will be sent to multiple labs for identical analysis.

Commented [NU8]: Other lab QC checks also assess lab bias (% Recovery). Consider use of a scatter plot to depict potential bias of field/lab data comparisons.

7.2.3. Accuracy

Accuracy is a measure of bias in a measurement system. The closer the value of the measurement is to the true value, the more accurate the measurement. Accuracy is expressed as the percent recovery of the surrogate or spike analyte from a sample or standard. Accuracy is dependent on traceability of instrumentation, standards, samples, and data methodology; blanks; surrogates; reference or spiked samples; performance samples, and equipment calibration. See table 7.1 for field equipment accuracy criteria which will meet the project DQOs.

Commented [NU9]: Will also need to insert the lab criteria (I have included a sample for this)

7.2.4. Representativeness

Representativeness is a qualitative term that refers to the degree to which data accurately and precisely represents a quality of the sample population being measured. Ensuring an appropriate sample design and minimum appropriate sample number will aid in appropriately characterizing the population and/or environmental condition being measured. Sample designs and sample attainment times are chosen in such a way to ensure both spatial and temporal representativeness of data. Project farms are selected randomly within the watershed to allow representation of various physical and climatic conditions to be accounted for. A log of field and/or laboratory conditions will aid in characterizing and identifying any conditions that might affect sample integrity. Representativeness is also evaluated, in part, by examining the chain-of-custody paperwork and verifying that the sample analyses were performed within the holding time.

7.2.5. Comparability

Comparability is a qualitative term that expresses the level of confidence that one data set can be compared to another and be combined for analysis. This applies both to different data sets collected within the current study, as well as data set sets outside of the study. The comparability goal is achieved through the use of reference methods and SOPs to collect and analyze representative samples, and reporting of analytical results in appropriate and consistent units and reporting limits. This goal is also achieved by maintaining consistency in sampling conditions, selection of sampling procedures, sample preservation methods, and analytical methods. Factors of comparability include sample collection method, handling and storage method, sample preparation and analysis procedures, holding times, stability, and QA protocols. If any of these measures differs significantly between sample collection sets, comparability may be compromised and data may not be able to be combined for analysis. In this case, separate analysis will be made or the data will be removed from the data set. To increase comparability of data sets, reference methods and SOPs will be followed. Consistency of laboratory methods will be maintained throughout the project.

7.2.6. Completeness

Completeness is a measure of the amount of valid (comparable) data needed to be obtained to satisfy the objectives of the study. Completeness is assessed by comparing the number of valid measurements collected with the criteria laid forth in the DQO. Following statistical procedures used to determine the number of measurements needed, will aid in increasing completeness of the data set. At least 80% of the data collected must meet the performance criteria outlined above for the data set to be considered complete. If criteria are not met, additional sampling rounds will need to be considered to satisfy the DQO.

7.2.7. Sensitivity

Sensitivity is the capability of a method or instrument to discriminate between measurement responses. In most cases, the sensitivity is the minimum concentration that can be measured by a method, instrument, or laboratory. Individual sensitivities are outlined in Table 7.1.

Table 7.1. Sensitivity and performance capabilities or field instrumentation

Instrument/Equipment	Parameter	Range/ Reporting Limits	Accuracy/ Instrument Sensitivity	Resolution	Units
YSI Professional Plus Multi-parameter Meter	Dissolved Oxygen (DO)	0 to 50	0.2 (±2%)	0.01	mg/L, ppm
	Temperature	-5 to 70	0.2 (±3%)	0.1	°C, °F, K
	Conductivity	0 to 200	0.001 (±0.5%)	0.001 to 0.1	µS, mS
	Ammonium	0 to 200	2 mg (±10%)	0.01	mg/L-N, mV
	Nitrate	0 to 200	2 mg (±10%)	0.01	mg/L-N, mV
YSI pH10 Meter	pH	1 to 14	±0.1	0.01	units
Kestrel 4000 Weather Meter	Temperature	-45 to 125	1	0.1	°C, (°F)
	Relative Humidity	0 to 100	3	0.1	%
	Barometric Pressure	8.86 to 32.48	0.01	0.05	in Hg, (PSI, mb)

	Wind Speed	0.4 to 60	±3%	0.1	m/s, (mph, km/hr)
	Dewpoint (calc)	-45.0 to 125.0	2	0.1	°C, (°F, %RH)
	Altitude	-2000 to 9000	15	1	m, (ft)
	Heat Index	-45.0 to 125.0	2	0.1	°C, (°F, %RH, inHg)
	Wet Bulb Temp	-45.0 to 125.0	2	0.1	°C, (°F, %RH)
	Wind Chill	0.04 to 60 m/s, -45 to 125	1	0.1	m/s/°C (mph/°F)
Watermark, Soil Moisture Meter	Soil Moisture	0 to 200	±5%	0.1	Centibars/kPa
Stratus Rain Gauge	Rainfall (total)	0 to 11	0.01	0.01	inches
General Tools T300-36 Soil Thermometer (36")	Temperature	0 to 105	1	1	°C, (°F)
Pranalytica Ammonia Analyzer	Ammonia	40 ppb - 100 ppm	40 ppb (10%)	0.01	ppm

Table 7.2. Laboratory analysis sensitivity (MDL), Acceptance Criteria, and ~~emthods~~methods

Sample Medium	Analyte	MDL[1]	Method[2]	Precision and Accuracy
Water (Soil and Surface)	Fecal Coliforms (~~MTF~~MPN)	<2/100mL	SM 9221 B & E	±40% N/A
	Total Nitrogen	0.10 mg/L	SM 4500-A	±30% 70-130%
	Nitrate	0.05 mg/L	SM 4500-NO3 D	±30% 70-130%
	Ammonia N	0.05 mg/L	SM 4500~~2~~-NH3 D	±30% 70-130%
	Total Phosphorus	0.2 mg/L	SM 4500-P C	±30% 70-130%
Soil	El. Conductivity	NA	WCC S -2.30	±30% 70-130%
	Organic Matter	0.10%	WCC S - 9.20	±30% 70-130%
	Total Nitrogen	1.0 mg/kg	SM 4500-A	±30% 70-130%
	Nitrate	0.5 mg/kg	WCC S – 3.10	±30% 70-130%
	Nitrite	0.5 mg/kg	SM 4500-NO2 B	±30% 70-130%
	Ammonia N	0.2 mg/kg	WCC S – 3.50	±30% 70-130%
	Total Phosphorus	2.0 mg/kg	WCC S – 4.20	±30% 70-130%
	pH	NA	WCC S – 2.10	±30% 70-130%
Manure	Moisture (DM)	0.10%	TMECC 03.09	±30%
	Nitrate	0.5 mg/kg	TMECC 04.02	±30%

Formatted Table

Commented [NU10]: Removed the EPA Method Column, as we discussed. Instead added the Precision and Accuracy Column.

				70-130%
	Total Nitrogen	1.0 mg/kg	TMECC 04.02	±30% 70-130%
	Ammonia N	0.2 mg/kg	SM 4500-NH3 D	±30% 70-130%
	Total Phosphorus	2.0 mg/kg	TMECC 04.03	±30% 70-130%
	pH	NA	TMECC 04.11	±30%
	Total Carbon	0.01%	TMECC 04.01	±30% 70-130%
	C:N Ratio	NA	Calculation	NA
Forage	Moisture (DM)	0.10%	AOAC 934.01	±30% 70-130%
	Nitrate	0.5 mg/kg	AOAC 968.07	±30% 70-130%
	Crude Protein N	0.01%	AOAC 990.03	±30% 70-130%
	Total Phosphorus	2.0 mg/kg	AOAC 958.01	±20% 80-120%
Air	Ammonia			
	Nitrous oxide, methane, carbon dioxide			

[1]MDL = minimum detection limit.
*[2]Analytical Method is the method used by Exact Scientific Services laboratory. These methods equate to specific and standard EPA methods (see column "EPA Method"). **WCC** = Western Coordinating Committee; **SM** = Standard Methods; **TMECC** = Test Methods for the Examination of Composting and Compost; **AOAC** = Association of Official Agricultural Chemist; **GC** = Gas Chromatography.*

8. SPECIAL TRAINING/CERTIFICATION

8.1. Project Personnel Training

All project personnel that will be obtaining field samples will be trained by the Field Team Leader in accordance with the appropriate SOP for each medium sampled. This will include an in-office detailed discussion of the methods, as well as an in-field demonstration and equipment use trial to ensure equal, consistent use across all project personnel.

The laboratories (Table 13.1) utilized for this project are ~~either~~ the Washington State Department of Ecology ~~DOE~~ and/or EPA accredited where applicable and have all necessary methods, training, and certification to run required analyses (Table 7.2).

The EPA requires that project personnel that will be using STORET attend a training workshop. All personnel responsible for data handling and storage will attend the STORET training as soon as it is available through EPA.

8.2. ARM User Training

The ARM system methodology and worksheets will be gone over by the Project Manager with each individual user prior to implementation on their farm. A detailed description of the ARM

Commented [NU11]: EPA does not accredit laboratories. WA ECY's accreditation program is out there for water and waste labs and is mandated where the data is presented to them for their use. However, labs will not be accredited for all parameters and matrices in this project (i.e., manure, forage, etc..) It is important though that the lab's have the stated capabilities to meet the measurement quality objectives of this project for the parameters and matrices upfront. So, in that sense, the lab's should be presented with these MQO's and selected based on the confirmation that they can meet those. You may even want them to provide you with a table of their detection limits for each of the parameters as verification that they have the capability.

system, including field risk ratings and worksheet inputs, will be located in their Diary Nutrient Management Plan. Tools such as links to forecasts, descriptions as how to conduct soil moisture analysis, pictures of vegetation cover density, etc., will be posted on our website for review. For each application event, the producer is requested to send in their ARM worksheet for verification and approval prior to applying manure to ensure they are conducting the process correctly. At the conclusion of the project, after the ARM system tools have been developed and thoroughly tested, a workshop will be conducted to introduce the system to farmers throughout the County (details of training not yet available). This level of oversight and training should ensure proper understanding and utilization of the ARM system tools.

9. DOCUMENTATION AND RECORDS

Documents and records will be kept in accordance with EPA standards for the duration of the project as a means of establishing consistency and documentation of project tasks and activities. Records will be kept in both hardcopy and electronic form. Coordination of all recordkeeping will be the responsibility of the Project Manager. Individual documents and information coordinators are outlined in Table 9.1.

9.1. Project Documents and Procedures

Hardcopies of all up to date QAPP, SOP, and other pertinent documents necessary to successfully carryout the project tasks, will be readily available to all project staff at both the WCD office and in the field operation material bins for the life of the project. Additionally, electronic copies of revised documents will be sent out electronically to all project personnel listed in the section *3 Distribution List* as well as field personnel as necessary.

9.2. Data Collection and Handling Records

All records associated with data collection, handling, and analysis will be kept by the Project Manager. These records include field logbooks documenting sample collection and handling, field notes, meteorological parameters, GPS data, chain-of-custody forms sent with field samples, QC sample records, and equipment calibration information. Data stored in both the WCD and STORET databases will be maintained by the project Data Manager.

9.3. Other Project Records

Other records maintained include project reports (bi-annual and final), billing and audit reports, project group minutes and rosters, and data summary reports. The following table outlines all documents to be produced and their retention time. In many cases a retention time of 4 years has been listed, as that is the lifespan of the project. If the project extends beyond 4 years, the record retention time will also extend to the new final project date.

Table 9.1. Records and documentation summary

Document/Record Type	Retention Time (yr)	Format (H, E)*	Location
Project Documentation			
QA Project Plan	4	H, E	Director, Project Manager, Project QA Officer

Standard operating procedures (SOPs)	4	H, E	Project Manager
Field Records			
Field and laboratory notebooks	6	H	Field Technicians, Project Manager
GPS data	6	H, E	Project Manager
Sample handling/labeling/custody records	6	H	Project Manager
Site information, maps, and photos	6	H, E	Project Manager
Analytical Records			
Inspection/Maintenance/Calibration records	4	H, E	Project Manager
Data Records			
STORET Database	4	E	Data Manager
Data spreadsheets (Excel or Access)	6	E	Data Manager
Original field data sheets	6	H	Project Manager
Assessment Records & Reports			
Meeting and presentation logs	4	H	Project Manager
Data summary reports	4	H, E	Project Manager
Quarterly and final reports	4	H, E	Administrator, Project Manager
Billing and audit reports	4	H, E	Administrator
**H = Hardcopy, E = Electronic*			

10. SAMPLING PROCESS DESIGN

The follow section describes the projects experimental design for data collection. The selected probability-based experimental design should give a representative view of the target population using a smaller subset of that population. In general, the goal of the sampling program outlined in this document is to monitor trends in environmental conditions based on current and modified practices. More specifically, the aim of the project is to assess the affect of different manure application schedules and guidelines on the partitioning and cycling of nutrients and pathogens using a systems approach by concurrently measuring concentrations in ground/soil water, surface water, air, and soil. Trends, correlations, effects, and relationships will be assessed individually for all constituents outlined in this sampling program using statistical tests such as ANOVA, linear regression, basic statistics comparison (mean, median, standard deviation, etc.), and when warranted, non-statistical descriptive measures such as percent differences, graphical interpretation, and trend discussion.

Commented [NU12]: Curt will have more comments on the sampling design.

The official project runs from July 1, 2010 to June 30, 2014. During that time period we expect four monitoring years starting in February 2011, with four seasons per year (2 in year four). The number of farms, fields, and samples taken is outlined below.

10.1. Sampling Design Rational

The sampling design for this project is broken down into various parts. First, test farms within the area of study (the watershed) are selected. Test farms are selected on either 1) a random basis where they come to WCD as plan updates are necessary and agree to participate in the study, or 2) they are selected from an area of interest within the watershed (systematic selection). Second, test fields are chosen from all fields available at a test farm. Since all fields can not be sampled, one or more fields are selected that are representative of the area (systematic selection). In the case of paired sampling efforts, two fields with the same characteristics will be chosen for accurate comparison. Third, test locations within the field are selected. Many fields have more than one soil type, so an area that represents the primary (>50%) soil type will be chosen when this is the case (stratified random selection). The location of the co-locate sample site within the field area will be randomly selected from a field grid. Areas that are not representative of overall field conditions or contain geological or wetland areas will be blocked off of the grid. The individual sample design and protocol of each parameter measured is outlined below. Parameters to be measured include: surface water, ground and soil water, soil moisture, air, soil, manure, forage, and meteorological conditions.

Commented [NU13]: Ground water still listed…

The in-field measurement system constructed for this project is designed to look at the partitioning of nutrients (primarily nitrogen and phosphorous) and fecal coliform in the air, surface runoff water, and soil water in the vadose zone of a manured dairy cropping system in Northwest Washington (Figure 10.1). In order to assess the complex interactions of nutrients and pathogens in a cropping system, and the effect of various manure applications on that system, measurement of soil water, surface water, air, soil, manure, forage, and meteorological parameters will be conducted (see Table 6.1). This comprehensive systems monitoring approach allows the monitoring of nutrient partitioning and loss pathways from the air to below the root zone (24” deep - what travels below this depth is assumed to be available for transport to groundwater, which will not be measured directly). Surface volatilization loss will be measured using hovering samplers and real-time analyzers (10.3.3), as well as meteorological measures (10.3.7). Surface runoff losses will be measured with in-stream up/down gradient and in-field overflow monitoring techniques (10.3.1). Available and immobile nutrients will be measured in soil (10.3.4), manure (10.3.5), and forage (10.3.6). Seasonal water table depth, measured to a depth of four feet, as well as soil water nutrient and pathogen transport will be measured at three different depths using lysimeters and soil cores (10.3.2). These measurements will allow us to observe the rate of transport of nitrate through the soil profile at different times of the year, and when paired with seasonal water table depths and/or application technologies and timing, can help us predict the contribution of nitrate to groundwater, or the retention in the root zone. This information is critical when looking for relationships between soil moisture, weather events, forage conditions, manure application rates and timing, volatilization potential, and plant nutrient availability.

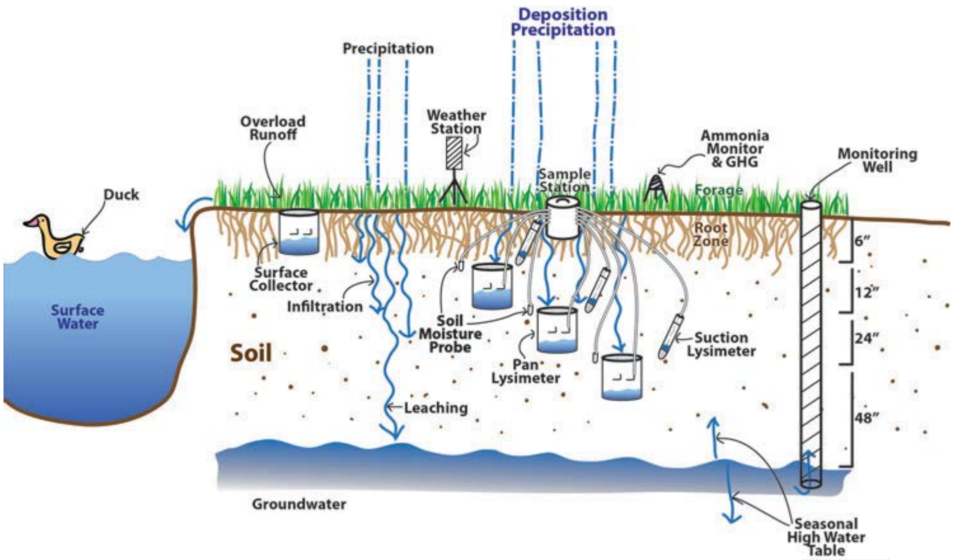

Figure 10.1. Field sampling diagram (not to scale) illustrating location and schematic of sampling equipment.

Commented [NU14]: If possible, recommend removing the monitoring well from the diagram, if you do not end up using any of the existing wells for the project.

10.2. Sample Strategy and Numbers

10.2.1. Test Site Number

Sample numbers are dependent on the parameter measured and the confidence level desired. We have chosen to sample multiple fields at 10 farms per year to account for variability in soil type, weather patterns, management, technologies, etc. throughout the watershed. Since there are no prior data to determine population variance or the CV for field conditions within the watershed, an exact sample size to meet pre-specified conditions is not available ($n = t^2CV^2/E^2$, where n = sample size, t = Student's t statistic for CV, CV = coefficient of variation, and E = acceptable error as a proportion of the mean). However, by using an iterative confidence interval approach to estimating sample size, we have determined that 10 sample farms is sufficient to minimize variability between farms at a 95% margin of error. The first year of the project, we will have five test fields/farms to assess sampling methods and strategies. Starting in year two, and pending the results of year one, the project will add approximately 10 additional farm/fields per year for a total of 35 farm/fields, which should be more than sufficient to reduce variability and allow a projection of results over the watershed area, rather than be limited to the sample site. However, comprehensive sampling of all mediums (surface water, soil water, soil, air, manure, and forage) and all analytes will only be conducted over the entire project period on test farms enrolled in years one, two, and three. This is because, while one year is sufficient to show a trend in variability between seasons, one year of data are not sufficient enough to account for variability in nutrient cycling within seasons. Farms enrolled in year four of the study will primarily be utilized for testing of ARM system tools and components and will have limited and targeted field testing done based on previous study results as to which measures are most important for entry into the ARM worksheet (i.e., nitrogen in soil, soil moisture, and soil temperature).

10.2.2. Field Numbers

In order to decrease variability within test farm sites, multiple fields per farm (1 to 3+) will be measured. A test field will be defined as an area of only one soil type. Based on that definition, one farm field can have multiple soil types and field test units. The number of test fields selected will depend on ARM risk rating characteristics, the variability between fields on the farm, and the crops grown. Variability is expected, but should be within the selected margin of acceptable error (10% CV). The selection process for test fields will be consistent for all test farms. Paired (same management, soil profile, manure, etc.) test and control fields will be used to measure the difference between application strategies (ARM vs. current timing guidelines) and practices (i.e., manure application technology, buffer width and type, crop type, etc.). Paired fields will need to be adjacent to each other to ensure they have the same soil type, weather influences, groundwater depth fluctuations, crop, and management. Paired field location and number will be selected based on availability. If a test field cannot be paired or split, the information obtained from said field will still be immensely useful to assess the relationships and correlations between all of the mediums. This type information is vital to the strengthening of the threshold parameters in the ARM worksheet.

Commented [NU15]: Do you feel this will be achievable? From discussion, I understand that ag fields are fairly uniform so perhaps this will not be an issue. (We would usually say 10% is much too tight for environmental sampling.)

10.2.3. Medium Numbers

The number of samples taken at each site throughout the year will vary depending on the medium. Current sampling protocols are designed to have the least amount of variability and still stay within sampling budget. The total number of samples (n) to be taken per medium, over the entire project lifetime (4 years) is shown in Table 10.1 (numbers subject to change). More specific frequencies of sampling are outlined in section 10.3. While it is not anticipated, if the CV is outside of acceptable limits, sampling protocols will be revised to include more sampling events to achieve the level of error specified in this plan.

Note: Sample number may change (no significant decrease expected) depending on additional outside funding, price adjustments, and project assessment. Any increase in sample number will benefit the project objectives.

Table 10.1. Estimated sample numbers over the project lifetime for each medium and analyte (number subject to change (+/-) with budget, sample protocol revision, and equipment)

Sample Medium	Analyte(s)	Estimated Number (n)
Water (Surface)	Fecal Coliform (FC)	1,935
	Total nitrogen	1,935
	Nitrate	96
	Ammonia-nitrogen	96
	Total phosphorous	1,735
	Dissolved oxygen (DO), pH, temperature, electrical conductivity (EC), nitrate, ammonia-nitrogen (NH3-N)	6,450
Water (Soil)	Fecal Coliform (FC)	20
	Total nitrogen	600
	Nitrate	25
	Ammonia-nitrogen	25
	Total phosphorous	300
	Dissolved oxygen, pH, temperature, electrical conductivity, nitrate, NH3-N	1,170
	Soil moisture	16,000

Soil	Electrical conductivity, organic matter (OM), total N, nitrate, nitrite, ammonia-nitrogen, total P, pH	1,095
	Total carbon	360
Manure	Moisture (dry matter), total N, NH3-N, total P, pH	1,100
	Total carbon	360
	Nitrate	10
Air	GHG (CO_2, CH_4, N_2O)	1,095
	Ammonia	1,095
Forage	Dry matter, crude protein nitrogen, total phosphorous, nitrate	180

10.3. Sample Types, Locations, and Frequencies

Each of the environmental parameters measured is outlined below along with sample locations and frequency of sampling. Actual analytes measured for each parameter are listed in Table 10.1. Section 11 outlines the sampling methods (Table 7.2) and procedures for each medium discussed in this Section. The standard operating procedure (SOP) for each medium outlines the equipment and supplies used in sampling as well as the procedural steps of sampling (i.e., calibration, collection, handling, preservation, records) and quality control. Refer to the specific SOP (Table 11.1) for details on in-field sampling procedures.

10.3.1. Surface Water

In-stream. Surface water will be collected from test fields that have adjacent waterways (i.e., field ditches, streams, creeks, rivers, wetlands, etc.). Surface water samples will not be taken from fields that do not have adjacent waterways. Prior to each measurement, the sample location will be noted with GPS coordinates, and field and weather conditions recorded. Then, a sample from each waterway located adjacent to the test field will be collected upstream (sampling location background), and downstream (source pollution) of the field and assessed using a paired model. The difference of the two measures is the pollution contributed by processes within that field. In order to make sure the same water "particle" is being sampled, the water flow velocity will be determined prior to sampling ($Q = d/t$, where Q = flow rate (ft/s), d = distance between point A and B (ft), and t = time from point A to B (s)). The flow rate will help determine the time necessary to wait between taking upstream and downstream water samples. A water quality sample will be taken 24 hours before and 24 hours after every field application (approximately 1-6 per year depending on crop). Additional samples will be taken during storm events when runoff events are possible (approximately four per year). Visual appraisal of field conditions and runoff events will also be conducted and recorded during storm events. If a waterway is dry or very low (<10% of normal flow), no samples will be taken. Samples will be taken at the same location for each measurement cycle to reduce variability.

Commented [NU16]: From EPA microbiologist Dr. Harris (SH from here on): If the runoff occurs more quickly than 24 hours, it might be a good idea to evaluate water quality during field application or at least sooner than 24 hours….

Overland. Secondary runoff measures will be taken within buffer areas (0-100 ft) to determine the effectiveness of buffers and manure setbacks at limiting nutrient and pathogen runoff. Measurement devises, similar to the 3 gal pan lysimeters described in 10.3.2 (Figure 10.2A), will be installed at a subsurface (1 inch) level to determine overland flow and concentration. The flow collectors will consist of a 3 gal bucket buried to 1 inch below the soil surface with a permeable lid topped with inert sand substrate to allow overland flow to be collected into the collection container. Flow collectors will be permanent installations over the project lifetime. Samples of pan contents will be taken after significant rain events in conjunction with stream measurements and all the same analyses will be conducted.

Commented [NU17]: SH: Not much point in testing FC, as the holding time is 6 hours.

10.3.2. Soil Water

Soil Water. Soil water samples will be measured in each test field using pan lysimeters (zero-tension, gravitational), tension lysimeters, and soil cores. While the pan lysimeter will be the primary method utilized for measurement of soil water, soil cores and tension lysimeters (Figure 10.2) will be installed as a method validation and secondary measurement at each depth. All three methods of soil water collection will be used in order to get an accurate picture of the various soil water processes and transport pathways occurring throughout the year under precipitation (pan), seasonal groundwater flux (tension), and non-precipitation soil moisture (tension, soil core) conditions. Lysimeters will be installed and soil cores taken in test fields at depths of 6, 12, and 24 inches and spaced 3 to 5 feet apart so that sample areas do not overlap. The sample area chosen for lysimeter installation will be representative of the majority (>50%) of the field.

Soil Core Extraction. Soil cores, obtained following the same methodology as soil samples in 10.3.4 and 11.2.4, will be measured for soil nitrate. A composite sample of 20-30 cores across the sample field will be taken for each depth (6, 21, and 24") with a handheld soil probe, thoroughly mixed, and a homogeneous sample will be sent to the laboratory for analysis following handling and storage protocols outlined in 11.2.4. For QA, a single sample will be taken directly above each pan lysimeter (6, 12, and 24") once every month concurrently with a pan sample (cores holes will be filled back in with local dirt). Soil nitrate values will be used for comparison and validation of the pan lysimeter method.

Tension Lysimeter. The tension lysimeters (Figure 10.2B) chosen for this study (Model 1900L; Soilmoisture Equipment Corp., Santa Barbara, CA) work by creating a vacuum inside the sampler that is greater than the soil water tension, thus allowing the soil water to flow from the soil pores into the ceramic cup sampler to be collected and tested. This is an effective way to measure soil water at specific soil horizons in saturated, wet, or heavy textured soils, but may overestimate soil concentration due to the accelerated wicking action imposed by the suction (Weihermuller et al., 2007). Therefore, we will have limited sites (2) with tension lysimeters co-located with pan lysimeters at 6, 12, and 24 inches, and will only use the data for method comparison to the pan lysimeter and soil cores. Samples will be taken once monthly at the same time as soil cores, and/or at the same time as pan lysimeter sampling.

Pan Lysimeter. Improved zero-tension gravitational pan lysimeters (Figure 10.2A) were chosen for this study because they tend to be best suited for collection of nitrate, phosphorous, and bacteria concurrently (Weihermuller et al., 2007). Pan lysimeters are passive samplers that collect soil water that has gravitationally percolated through the soil profile and into a filtered collection bucket. The cumulative liquid collected is pumped out of the bucket and sampled. Pan lysimeters give a description of the cumulative contribution of gravitational soil water through a specific soil profile to a measured depth over a given period of time, and can be set at various depths to examine the spatial and temporal transport of nutrients through the soil profile. However, since they can only measure soil water that has naturally flowed through the soil profile, they are only effective with precipitation. Studies have demonstrated that zero tension lysimeters have limitations in collection efficiency in dry soil (Zhu et al., 2002) and non-forage fields (52%: Jemison and Fox, 1992; 48%: Zhu et al., 2002); but perform better during collection under forage fields (Toth et al., 2006), and with the more recent developments in the various types of pan lysimeters (Weihermuller et al., 2007), such as the one used in this study (Figure 10.2A).

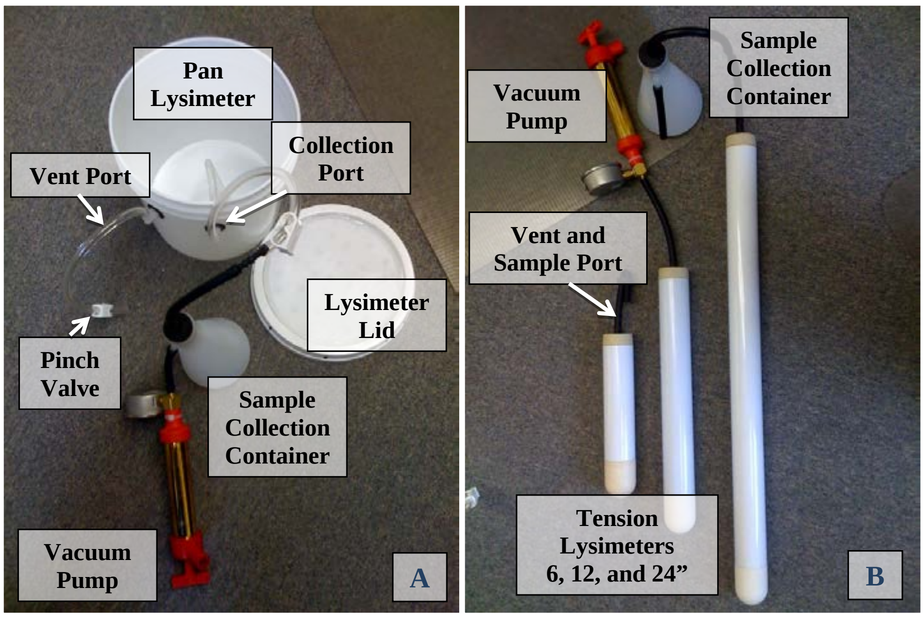

Figure 10.2. Pan lysimeter (A) and tension lysimeter (B) set-up. The pan lysimeter is a three gal bucket with a modified, felt and polypropylene covered top, and 0.25 inch ports for venting and sample collection. The tension lysimeters (Soilmoisture Equipment Corp, CA) are 6, 12, and 24 inches in length with ceramic tips and a tube for tension and sample collection.

The lysimeter used in this study (open, zero tension) is designed collect the gravitational water flowing through the soil pores above the sampler. Water flows from the soil, through the filtered and perforated lid and into a three gallon bucket. The bucket has a vent and collection tube, both of which reach to the surface through a protective PVC pipe. Soil water is extracted from the bucket with Tygon tubing into a measured collection container so that volume can be recorded and compared to precipitation amount and samples transferred to vials. The lysimeter is installed on a side cut, leaving undisturbed soil above the pan. This is done by excavating a pit and installing the samplers into the exposed area, rather than digging a hole and burying them. During installation, soil depth above and between the pans will be measured so that a known volume of soil above the pan is recorded for transport calculations. To maintain hydraulic contact with the soil above the pan, the pan lid is covered with a double layer of polypropylene filter mesh and polypropylene felt fabric and a topped with a one inch layer of inert sand, the combination of which has been shown to support a greater conveyance of water into the lysimeter, rather than around it (Thompson and Scharf, 1994). Proper field testing of the collection system will be conducted prior to launching our full monitoring campaign to account and correct for any limitations of our system.

Since soil water samples can only be taken when there is soil water present, pan lysimeter sampling will not be conducted when the soil is dry (co-located soil moisture probes will help determine moisture content), or there has been no significant precipitation (variability for each soil type will be determined). When conditions are favorable (over ~0.25” of precipitation), soil water samples will be taken 24 hours after each precipitation event over 0.25-0.50 inches (a precipitation “event” is a continuous period of precipitation lasting 24 hours [0800 to 0759 h] or less) and/or soil moisture levels at 100%. Tension lysimeter and soil core water will also be sampled once every two weeks from September through February, and monthly from March to August, to characterize soil water at various depths over the year. When the water table is above a lysimeter depth (determined by observing monitoring pipe), a sample will only be taken immediately after the depth reaches the pan top and after it has receded below the pan. These samples will be marked as such and used for observational purposes.

Water Table Depth. For those fields without monitoring wells installed, a water table depth monitoring tube will be installed down to 4 to 6 feet below the soil surface following ~~DOE~~Ecology Standards for Construction and Maintenance of Wells and USACOE guidelines. The tube will be a 4 or 6 foot, 2 inch diameter PVC pipe with a float, installed with a boring probe. When not in use, the tube will be tightly capped. The tube will help determine the groundwater depth to surface level (0-6 feet) at all times of the year to see its effect on transport and dilution of nutrients in the soil profile. In areas where installation of a monitoring tube is not practical or allowed, a hole, no deeper than 4 feet will be dug, or secondary factors (i.e., ditch levels, creek levels) will be utilized for determining groundwater depth to surface.

Soil Moisture. Soil moisture will be determined using a resistance (gypsum) block. To monitor soil moisture across the field, two gypsum blocks will be buried 12 inches deep at representative locations in each field, and an additional three blocks will be co-located with pan lysimeter locations at 6, 12, and 24 inches deep (only 12 and 24 in corn fields due to tillage practices). Each block will be installed with a 1.5 inch diameter auger and soil will be packed back after installation. The location of each block will be marked with GPS coordinates. Measurements will be taken each time any other constituent is measured, including before and after manure application, during big storm events, randomly throughout the year at the same times as soil, surface water, and soil water samples, and at any other time of interest. When gypsum blocks are being installed, a characterization of the soil profile (soil core) above the block will be recorded.

10.3.3. Air

Ammonia and greenhouse gas (nitrous oxide, methane, carbon dioxide) measurements will be taken one day before and at 1, 2, and 7 days after each manure application event. Ammonia and greenhouses gases will be also sampled randomly once monthly throughout the year, not to coincide with manure application events. All sample locations will be recorded with GPS so that subsequent samples may be taken in the same area.

Ammonia. Ammonia will be measured using a photoacoustic, continuous, real-time analyzer (Nitrolux-S, Pranalytica, CA), which has been approved for use at animal feeding operations by the EPA Environmental Technology Verification Program (2004), along with a surface collection system. Two types of surface collection systems will be utilized: point and composite. The point system consists of one HDPE sampling line, which is staked 4 inches above the ground surface, connected directly to the ammonia analyzer, and sampled at a rate of 1 lpm. This set-up is used when a single and defined point is desired to be measured. The composite surface collection system consists of 6 HDPE sampling lines protected by a 6 inch diameter PVC cap staked 4 inches above the ground surface. The cap is used to prevent moisture, dust, and dry deposition of gas from entering the sampling lines. The sampling lines, staked randomly in a set area, collect ambient air under vacuum into a composite sampling device. The PVC sampling device pulls air from the sampling lines at equal rates and mixes it in a closed, circulated container. From this mixed sample, the real-time ammonia analyzer actively collects a sample of air at a fixed rate of 100 cc/min. Samples are logged every 120 seconds for accurate analysis of surface ammonia concentration trends and variations over time. The system is unique because it does not disturb the normal surface flux behavior, and thus does not alter the rate and concentration of surface emissions like other measurement devices can (i.e. flux chambers, wind tunnels, etc.).

GHG. Greenhouse gases will be measured on-farm using a syringe collection technique method, where ambient air is drawn into a 30 ml syringe at a constant rate (1 ml per second). The sample in the syringe is then injected into a pre-evacuated 12 ml Exetainer (Labco Limted). Both ambient and plot samples, which will be co-located with the soil water sampling locations, will be taken. These measurements, conducted in partnership, will be sent to Agriculture and Agri-Food Canada for analysis.

10.3.4. Soil

Soil Sample. Soil samples will be taken using a simple randomized design with composite analysis. Every test field will be sampled at one (0-12 inches) to three depths (0-6, 6-12, and 12-24 inch). Depths were chosen because they are at plow depth, root zone depth, and below root zone depth, respectively. Samples will be collected before each manure application to evaluate agronomic application rates. Samples, co-located with ground/soil water equipment, will also be taken once monthly from September to February at 6, 12, and 24 inches at the same time as soil water samples and tested for nitrate. All sample locations will be recorded with GPS so that subsequent samples may be taken in the same area. An appropriate number of samples will be taken for each depth on each test field according to field size, procedures for EPA randomized grid designs, mixed as a composite sample, and sub-sampled. On average, the number of sample cores that will make up a composite sample will be 20-30 samples for each of the various sample depths (never less than 10). For fields over 30 acres in size, we will take one randomly located sample per one acre grid point (Reetz, 2001; Ferguson and Hergert, 2009) up to the total acres (for example; a 45 acre field will have 45 samples per composite). One composite sample per field, per depth, plus any QA duplicates, will be sent for analysis.

Soil Temperature. Soil temperature at surface (0), 6, 12, and 24 inches will be determined with a hand held probe thermometer (36 inch) at all soil-water, air, and soil sample locations at each sampling. Measurement locations will be marked with GPS and results recorded in a field logbook.

10.3.5. Manure

Manure samples will be taken at each manure application event on every test field. Two types of samples will be taken, one that is representative of the entire field (composite), and one that is specific to the location of the pan lysimeter locations (point). The point sample will help us understand the specific nutrient profile being applied over the lysimeters, which may contribute to the soil and soil water nutrient values measures in lysimeter samples. Depending on lagoon management and application technology, manure applied to farm fields can vary in concentration throughout the application time period. Studies show that if the lagoon is agitated, which is the most common practice, only 3 to 5 samples are needed to adequately represent the lagoon nutrient profile. If not agitated, 40 to 60 samples are recommended (Dou et al., 2001). Depending on manure application technology (i.e., big gun, drag hose, or tank), five randomly located composite samples will be taken across the selected test field during application by the catch method (plus one will be taken over the pan lysimeter location for point sampling). Forty samples will be taken if the lagoon is not agitated prior to application. If tests show consistency between the composite and point samples (<10% variation), then only the composite sample needs to be taken at each application event.

10.3.6. Crop/Forage

Both composition and crop yield data (lbs/acre) will be obtained at each harvest/cutting for each test field. This is approximately four-six samples for grass and one for corn per year. Yield will be measured immediately prior to harvest by using a box and cut method where a known area is hooped off (3 ft diameter) and cut by hand at approximately the same height as the harvesting equipment. The total yield (Y) in lbs/acre is measured by $Y = (Y_{wet} \text{ x } DM)/Area$, where Y_{wet} is the wet weight of the forage harvested in the field (lb), DM is the dry matter determination by the lab (%), and $Area$ is the total area of the sample hoop (acre). A yield estimate from the producer will also be obtained and recorded for comparison (typically a truck weight measurement). After the field is cut by the producer, a composite grab sample that is representative of the entire field will be taken and sent in for total analysis.

10.3.7. Meteorological

Meteorological data including ambient temperature, relative humidity, wind speed, wind direction, pressure, altitude, dewpoint, and wet bulb temp will be recorded in the field using a portable handheld weather monitor (Kestrel 4000). The weather monitor will be set up in the field during sampling campaigns at the same location as soil moisture equipment. Data will be recorded at various heights (i.e., ground level, 6 feet) depending on the parameter being measured (e.g., air quality, surface runoff, etc.). See Table 7.2 for instrument details.

Precipitation will be measured at each test site with a rain gauge. The rain gauges will be installed permanently on-site according to proper installation procedures outlined by the manufacturer. Observations will be made on a daily basis by the farm operator and recorded in a log book.

Meteorological data will also be recorded from permanent sites located throughout the county (see Table 10.2). Field data will be compared to these sites for correlation and validation purposes. Forecast data will also be obtained and recorded from external sites. Table 10.2 shows various meteorological sites and their measures to be consulted during the project.

Table 10.2. Meteorological sites consulted and measures recorded as part of the project data

Site	Address	Measures Recorded	Days Forecasted Out
NOAA	www.wrh.noaa.gov	Temp, precip (predicted, 6hr), RH, wind speed, wind dir	4

NOAA - Quick Forecast	forecast.weather.gov	Temp, precip (predicted, 12 hr)	3
University of Washington - Probcast	www.probcast.com	Temp, precip (predicted, 12 hr)	2.5
Farmers Forecast	www.weather.com	Temp, precip (predicted, 12 hr), wind speed, wind dir, GDD*	1.5
Washington State University - AgWeatherNet	weather.wsu.edu	Temp, precip (current), soil moisture, soil temp, wind speed, solar radiation, leaf wetness	Current, Historical
Farm West	www.farmwest.com	Temp	5
Weather Underground	www.wunderground.com	Temp, precip (historical), RH, wind speed, wind direction	2, Historical

**GDD = Growing Degree Days*

11. SAMPLING METHODS

The procedures for sample collection including methods, equipment, collection materials, preservation techniques, and decontamination procedures are listed below as well as in Table 7.2 and 11.1. The standard operating procedure (SOP) for each medium, which outlines the equipment and supplies used in sampling as well as the procedural steps of sampling (i.e., calibration, collection, handling, preservation, records) and quality control, are referenced in Table 11.1 and available from the Project Manager at any time. Sample collection for water quality will be conducted following guidelines outlined by Department of Ecology (Ward, 2001) and/or the U.S. Geological Survey (USGS, 2006). All sample container types, and volumes are specified by the laboratory. All holding times and storage conditions are specified by the laboratory following EPA required procedures outlined in 40 CFR Part 136 (Table 11.1). Quality control procedures are outlined in Section 14 and Table 14.1.

11.1. Sample Collection, Preparation, and Decontamination Procedures

11.2.1. Surface Water

In-stream. Three samples will be taken for water quality samples, one for fecal coliform analysis (FC), one for lab analysis (lab), and one for field analysis (field). Surface water will be collected into 120 ml (FC), 250 ml/1000 ml (lab), or 500 ml (field) sterile environmental testing bottles provided by the state-certified testing laboratory. For the laboratory samples, a 250 ml sample will be collected for each individual analyte, or a 1000 ml sample for all analytes (depending on test being conducted). Each labeled bottle will be uncapped and inserted into the center of the stream flow or out 5 feet from the stream bank (whichever is most appropriate for the waterbody size), and a sample will be collected into the bottle. The FC sample will be collected first into a 120 ml bottle, and then the 250/1000 and 500 ml bottles will be collected in unison. The 120 ml and 250/1000 ml sample containers will be capped immediately, taking care not to touch the lip of the bottle or inside of the cap, and placed in a chilled (≤6 °C), UV protected cooler. If not able to get to the lab within 6 hours of collection, samples to be analyzed for total phosphorous, nitrate-nitrite, and/or ammonia nitrogen with be acidified with sulfuric acid (H_2SO_4) to pH<2 for preservation. The clean field analysis probe will be inserted into the 500 ml container for real time analysis of measures listed in Table 11.1. All results will be logged into the meter as well as recorded into a field notebook. After the analysis is complete, the uncontaminated sample will be

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returned to the waterway from which it came and the analysis container and sample probe will be rinsed thoroughly with DI water. FC and lab samples will be stored in the chilled cooler and taken to the laboratory for analysis the same day. If same day drop off is not possible, samples will be stored in a refrigerator overnight and taken to the laboratory within 24 hours of attainment. A field replicate, treated in the exact same way, will be taken every twentieth sample for FC and lab samples and sent for analysis. Field samples will be split every twentieth sample for QC analysis (Table 14.1).

Overland. Any overland flow collected by the bucket sampler will be pumped through Tygon tubing with a hand pump from the bucket into a sterile 120 ml (lab), 250/1000 ml, and 500 ml container. If there is excess liquid in the bucket, it will all be pumped from the container down-gradient into the field so that the preceding sample period is distinguished from the last. The 120 and 250/100 ml container will be handled in the same manner as describe above for lab samples including acidification, and the 500 ml container will be handled as a field sample. All analysis will be the same as for in-stream samples. If there is less than 250 ml of sample in the container, preference will be given to the in-field sample. Excess will be sent to the laboratory for analysis.

11.2.2. Soil Water

Soil Water. Soil water will be collected as described in section 10.3.2. using both a pan and tension lysimeter. For the pan lysimeter, soil water collected in the pan will be pumped through Tygon tubing using a hand pump and into a sterile collection vessel. The sample will be transferred from the collection vessel into 120 ml (FC, lab) and 250/1000 ml (lab and field) sterile environmental testing bottles provided by the state-certified testing laboratory. For the laboratory samples, a 250 ml sample will be collected for each individual analyte, or a 1000 ml sample for all analytes (depending on test being conducted). The lab sample will be capped immediately, taking care not to touch the lip of the bottle or inside of the cap, and placed in a chilled (≤6 °C), UV protected cooler. If not able to get to the lab within 6 hours of collection, samples to be analyzed for total phosphorous, nitrate-nitrite, and/or ammonia nitrogen with be acidified with sulfuric acid (H_2SO_4) to pH<2 for preservation. The clean field analysis probe will be inserted into the filed 250 ml container for real time analysis. All results will be recorded by the meter as well as entered into a field notebook. In the case of low collection volumes (<100 ml), fill preference will be given to the laboratory sample. If a field sample is not able to be obtained, field measures (i.e., nitrate, ammonium, EC, DO) will be conducted by the laboratory instead. After the analysis is complete, the uncontaminated sample will be returned to the field from which it came and the collection vessel and sample probe will be rinsed thoroughly with DI water. Lab samples will be stored in a chilled (≤6 °C) cooler and taken to the laboratory for analysis the same day. If same day drop off is not possible, samples will be stored in a refrigerator overnight and taken to the laboratory within 24 hours of attainment. A field replicate, treated in the exact same way, will be taken every twentieth sample for lab samples and sent for analysis. Field samples will be split every twentieth sample and analyzed for variability (Table 14.1).

Soil Moisture. Soil moisture will be determined using resistance (gypsum) blocks buried in each test field and marked using GPS. Resistance blocks work by absorbing water into the gypsum, which is cast around two electrodes, dissolving some of the gypsum and effectively lowering the resistance for an electrical current to be passed between the two electrodes. The more water that enters the gypsum block, the lower the resistance. To ensure proper functioning, the block will be installed at the proper depth using an auger no wider than the probe diameter. After it is

Commented [NU19]: SH: Coliform testing requires a 6 hour holding time, so next day analysis is not appropriate if the samples are being used for compliance or research.

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inserted into the soil profile, the block will be covered and the soil temped firmly to remove any possible air pockets in the soil which can skew readings. To measure the soil moisture level, the block electrodes will be connected to a handheld monitor and the reading recorded in a field log book. Gypsum blocks will be left in the soil for the entire sampling period. If one is lost due to plowing activities, etc., it will be replaced in the same area.

11.2.3. Air

Ammonia. Ammonia will be measured using a photoacoustic real-time analyzer (Nitrolux-S, Pranalytica, CA) and surface collection system as described in section 10.3.3. Sample locations will be co-located with soil water samplers, as well as randomly throughout the field. Samples are logged every 120 seconds. After a one to two cycle adaptation period, sample areas will be measured for approximately 10 minutes prior to moving to the next sample location. A background (ambient) sample will be taken for a minimum of 10 minutes prior to sampling for validation/quality control. All ammonia data is logged into the analyzer, downloaded onto a USB, and analyzed with Excel.

GHG. Greenhouse gas samples will be taken using a syringe technique. Ambient samples will be taken by slowly drawing air into a 60 ml polypropylene syringe (Becton Dickinson, Rutherford, NJ) at a rate of 1 ml/sec and injecting the air into a labeled 12 ml vial (Exetainer, Labco Limted, UK). Plot samples will be taken by pulling an air sample from the composite sampler outlined above at the same time as ammonia measurements are made. Samples will be injected into 12 ml labeled vials, stored in a UV protected container (temperature <20 °C), and sent to Agriculture and Agri Food Canada for analysis using gas chromatography (GC) fitted with an electron capture detector (Model 3800, Varian Inc., Walnut Creek, CA) within seven days of each sampling event. For quality control, a field blank and a split field replicate (sent in as a blind duplicate), will be taken once every sampling period and sent in for analysis (Table 14.1).

11.2.4. Soil

Soil Sample. Soil samples will be taken at one (0-12 inches) to three (0-6, 6-12, and 12-24 inches) depth segments using a clean and dry handheld soil probe. If a foot driven soil probe is impractical due to soil type (dry, rocky, etc.), a hand held auger will be used to extract the sample. To obtain the segments with the probe, a 24 inch soil probe will be inserted into the soil and the core extracted. The core will then be divided into the three segments using a ruler. Each sample for each depth will be transferred into a separate, clean plastic bucket and mixed thoroughly using a gloved hand. A 500 ml homogeneous sub-sample of each composite sample will be taken and transferred into two 1 liter, labeled, sterile plastic bags. Samples will be stored and transported in a chilled (<10 °C), closed container. The container will be maintained under dry conditions using frozen gel packs. One sample will be stored for reference at -20 °C and the other will be taken to the laboratory on the day of sampling. If same day drop off is not possible, samples will be stored in a refrigerator for no more than 48 hours prior to transport to the laboratory. A field replicate, treated in the exact same way, will be taken every twentieth sample and sent in for analysis (Table 14.1). The soil probe or auger will be rinsed with DI water and wiped clean after use at each field site.

Soil Temperature. Soil temperature at surface (0), 6, 12, and 24 inches will be determined with a hand held probe thermometer (36 inch) at all soil-water, air, and soil sample locations at each sampling. Measurement locations will be marked with GPS and results recorded in a field logbook.

11.2.5. Manure

Manure samples will be taken for each test field at each manure application event using the best available sampling guidance (Rieck-Hinz et al., 2003; Wallace, 2008). The catch sample method used is specific to the type of manure application technology (i.e., in-tank, big gun, drag hose or tank), each of which is outlined in the SOP for manure sampling (ARM-04-M1.0). In each case, a point sample, collected over the pan lysimeter locations, and a composite sample of manure will be collected into a bucket, thoroughly mixed, and a homogeneous 1,000 ml sub-sample will be taken while the sample is in motion to account for solid suspension. The sample will be transferred into a sterile plastic sample container (do NOT use glass and do NOT fill more than 3/4 full to allow for gas expansion). Samples will be stored and transported in a chilled (≤6 °C) cooler. Samples will be taken to the laboratory within 12 (preferable) to 48 hours of collection. If samples cannot be taken to the laboratory in that timeframe, they will be put in the freezer at -20 °C until they can be transported to the lab. A field replicate, treated in the exact same way, will be taken every twentieth sample and sent in for analysis (Table 14.1).

11.2.6. Crop/Forage

Crop yield data (lbs/acre) will be obtained at each harvest/cutting as described in section 10.3.6. For forage/crop composition, a composite sample from each harvest will be obtained by grab method, thoroughly mixed in a clean bucket, sub-sampled, and placed in a clean one liter plastic bag. Samples will be stored dry in and transported in a chilled (≤10 °C), closed container. One sample will be stored for reference at ≤4 °C and the other will be taken to the laboratory on the day of sampling. If same day drop off is not possible, samples will be stored in a refrigerator for no more than 48 hours prior to transport to the laboratory. A field replicate, treated in the exact same way, will be taken every twentieth sample and sent in for analysis.

11.2.7. Meteorological

Meteorological data will be recorded in the field using a portable weather station (Kestrel 4000; Nielsen-Kellerman, Boothwyn, PA). The station will be taken to each sample location and parameters will be logged by the station in 2-3 second intervals over the entire sampling period. The current weather parameters will also be recorded in a log book at the start and end of each sampling exercise for all mediums sampled. Precipitation measurement will be recorded and reset at each sampling event. Data will be entered and/or downloaded after each sample day and analyzed and stored accordingly.

Table 11.1. ~~Analytical methods~~Standard Operating Procedures, and sample collection and storage requirements for mediums and analytes (maximum holding times for water mediums are taken from 40 CFR Part 136; holding times for other mediums are based on laboratory recommendation). Analytical methods are listed in Table 7.2.

Sample Medium	Analyte	Standard Operating Procedure (SOP)	Container	Sample Storage & Preservation	Holding Time (collection to analysis)

Water (Surface and Soil)	Fecal Coliforms (MTF)	ARM-01-SW1.0 (Soil Water) ARM-02-W1.0 (Surface Water)	120 ml sterile bottle	Ice (4°C ± 2°C) and 0.0008% $Na_2S_2O_3$ if Cl^- present	6 hr at ≤10 °C (EPA); 6-30 hrs at <4 °C (WS~~DOE~~ECOLOGY)
	Nitrate		250 ml bottle for individual or 1 liter bottle for all test	Ice (4°C ± 2°C)	48 hr at ≤6 °C
	Total Nitrogen			Ice (4°C ± 2°C); acidified with H_2SO_4 to pH<2	28 d at ≤6 °C if acidified with H_2SO_4
	Ammonia N				
	Total Phosphorus				
Soil	Electrical Conductivity	ARM-03-S10	Ziploc sterile plastic bag	Dry, closed container; Ice (4°C ± 2°C)	48 hr at ≤6 °C (dry); or indefinitely at -20 °C
	Organic Matter		Ziploc sterile plastic bag		
	Total Nitrogen		Ziploc sterile plastic bag		
	Nitrate		Ziploc sterile plastic bag		
	Nitrite		Ziploc sterile plastic bag		
	Ammonia N		Ziploc sterile plastic bag		
	Total Phosphorus		Ziploc sterile plastic bag		
	pH		Ziploc sterile plastic bag		8-24 hours
Manure	Moisture (DM)	ARM-04-M1.0	Ziploc (solid) 250 ml liquid individual or 1 liter bottle for all test	Dry, closed container; Ice (4°C ± 2°C)	48 hr at ≤4 °C; or indefinitely at -20 °C
	Nitrate				
	Total Nitrogen				
	Ammonia N				
	Total Phosphorus				
	pH				
	Total Carbon				
	C:N Ratio				
Forage	Moisture (DM)	ARM-06-F1.0	Ziploc sterile plastic bag	Dry, closed container; Ice (4°C ± 2°C)	48 hr at ≤6 °C (dry);
	Nitrate		Ziploc sterile plastic bag		
	Crude Protein N		Ziploc sterile plastic bag		
	Total Phosphorus		Ziploc sterile plastic bag		

Commented [NU22]: SH: If the testing is compliance or if the data will be used for future regulation, the 6 hour holding time is essential. WDOE has no regulatory authority to alter EPA's mandated holding time for compliance testing.

Commented [NU23]: No mention of the 6hr HT without preservation as listed in previous section…

Air	Methane, nitrous oxide, carbon dioxide	ARM-05-A1.0	12 ml Exetainer	Cool, dry, dark box	6 months at ≤20°C

11.2. Plan for Sampling or Measurement Failure

All sampling procedures and protocols assume proper functioning of equipment as well as proper attainment, processing, and delivery of samples. In the event that something does not go as planned during field sampling, back-up protocols will be in place. If the problem is beyond available protocols or a simple fix, the field team may identify and determine an alternative course of action, which must be approved prior to implementation by the WCD Project Manager. The problem and corrective action will be documented in the field log book.

To necessitate quick action, extra sample vials/bags, probes, tubing, etc. will be available in the field. If an problem occurs with field sampling equipment that is unable to be solved in the field, it will be replaced as quickly as possible, as back-ups are not usually feasible due to cost. If samples are not properly stored, or lost, a make-up sample day will be scheduled if possible. If this is not possible due to weather conditions, etc., the missing data will be noted and appropriately documented in the data set.

12. SAMPLE HANDLING AND CUSTODY

Sample processing and handling is a vital part of the organization, integrity, and longevity of the sample protocol. The following explains the storage and transport conditions of the samples, the labeling and tracking system, and the chain of custody.

12.1 Sample Storage and Transport

As outlined in Section 11, all samples will be collected into the proper containers, preserved as necessary, and placed into a chilled temporary storage cooler, and transported to either a secondary holding area (fridge at 4° C or freezer at -20° C) or the laboratory according to maximum holding times listed in Table 11.1.

12.2. Sample Handling and Tracking System

All samples obtained will be recorded in ink in a bound field log book. Any corrections to information entered into the log book will be lined out using a single line and signed and dated by the sampler. The information recorded will include:

- date,
- time of each sample collection,
- GPS coordinates of each sample location,
- site number,
- field number,
- sample number (add a “D” for duplicate, “S” for split, and “B” for blank),

- sample medium type,
- analysis being performed (lab or field),
- weather parameters and conditions,
- field conditions (crop, cover density, ponding, etc.),
- person performing sampling,
- laboratory sent to,
- and holding time between collection and analysis.

Any other noteworthy items will also be recorded including photos taken to document field conditions and sample procedures. For samples analyzed in the field (dissolved oxygen, pH, temperature, conductivity, nitrate, ammonium-N, soil moisture, ammonia, and meteorological conditions), the same information will be recorded along with analyte results.

All sample containers will be labeled according to a code system which contains information including:

- sample type (i.e., medium, analyte, technology),
- site number,
- field number,
- date,
- and sample number (add a "D" for duplicate and "B" for blank).

When possible, the label code will be written directly onto the sample container in permanent ink, otherwise, the sample identification information will be written on a label, which will be affixed to the sample container.

12.3. Chain of Custody

Samples will be packaged and shipped, picked-up or hand delivered to the laboratory as soon as possible (see Table 11.1 for holding times) by the field technician. A chain-of-custody form, supplied by the laboratory, will be completed in the field at the time of sampling and submitted with samples. Both the date and time of sample relinquishment (field manager) and receiving (laboratory) will be recorded on the form. Copies of forms will be retained by the Project Manager.

13. ANALYTICAL METHODS

Most of sample analysis will be conducted by analytical laboratories that have methods (Table 7.2), SOPs, performance standards, and reporting procedures in place according to approved (i.e., EPA or DOE) protocols that meet project quality objectives. These documentations are available by the laboratory upon request. In-situ field sampling will be conducted following procedures outlined by the manufacture or approved in the QAPP.

Samples designated for off-site analytical laboratory analyses will be submitted to the laboratories specified in table 13.1. Table 7.2 summarizes the laboratory MDL and methods to be used for this project.

All instruments and equipment used during field and fixed laboratory sample analyses will be operated, calibrated, and maintained according to the manufacturer's guidelines and recommendations, as well as criteria set forth in the applicable analytical methodology references (see Section 15 and 16 and appended SOPs).

In cases where laboratory results exceed QC acceptance criteria, reextraction and/or reanalysis will occur as indicated in the applicable analytical method. The respective laboratory analysts will be responsible for ensuring that appropriate sample analysis procedures are followed and take appropriate actions to ensure deficiency correction.

13.1. Analytical Methods

All samples will be collected, handled, and processed as described in sections 11 and 12. Standard operating procedures (SOP), methods, and laboratories are outlined for each analyte in Tables 7.2 (methods), 11.1 (SOP), and 13.1 (laboratories). The laboratories used will follow the analytical methodology specific and their lab SOPs for analysis. It is unexpected, but if any modification of method needs to be done by the lab, it will be stated in the laboratory's SOP and amended in the QAPP. All SOPs used for in-situ field sampling will be made available by the Project Manager.

Table 13.1. Laboratory used for matrix analysis and data turnaround time (refer to Table 7.2 for methods)

Matrix	Analyte*	Data Turn Around Time	Primary Laboratory	Secondary Laboratory
Surface Water	Fecal Coliform	48 hours	Exact Scientific Services 3929 Spur Ridge Lane, Suite 1 Bellingham, WA 98226 (360) 733-1205	Avocet Environmental Testing 1500 North State Street Bellingham, WA 98225 (360) 734-9033
	Total N, TKN, total P, nitrate	48 hours	Exact Scientific Services 3929 Spur Ridge Lane, Suite 1 Bellingham, WA 98226 (360) 733-1205	Avocet Environmental Testing 1500 North State Street Bellingham, WA 98225 (360) 734-9033
	DO, temperature, conductivity, nitrate, ammonium-N	Immediate	In-Situ - YSI Pro Plus Meter	Exact Scientific Services 3929 Spur Ridge Lane, Suite 1 Bellingham, WA 98226 (360) 733-1205
	pH	Immediate	In-situ pH Probe	Exact Scientific Services 3929 Spur Ridge Lane, Suite 1 Bellingham, WA 98226 (360) 733-1205

Commented [NU24]: SH: Getting results in 48 hours using SM 9221F may not be possible. Unless A-1 is used; otherwise, it can take up to 72 hours to obtain a negative result for FC.

Ground/Soil Water	Total N, TKN, total P, nitrate	48 hours	Exact Scientific Services 3929 Spur Ridge Lane, Suite 1 Bellingham, WA 98226 (360) 733-1205	Avocet Environmental Testing 1500 North State Street Bellingham, WA 98225 (360) 734-9033
	DO, temperature, conductivity, nitrate, ammonia~~um~~-N	Immediate	In-Situ - YSI Pro Plus Meter	Exact Scientific Services 3929 Spur Ridge Lane, Suite 1 Bellingham, WA 98226 (360) 733-1205
	pH	Immediate	NA	Exact Scientific Services 3929 Spur Ridge Lane, Suite 1 Bellingham, WA 98226 (360) 733-1205
	Soil Moisture	Immediate	In-Situ - Gypsum Block	NA
Air	Ammonia	Immediate	In-Situ - Pranalytica,	NA
	Methane, nitrous oxide, carbon dioxide		Agririculture and Agr-Food Canada Research Laboratory 6947 Highway 7 PO Box 1000 Agassiz, British Columbia V0M 1A0 604-796-2221	NA
Soil	EC, OM, FC, total N, nitrate, total P, pH	48 hours	Custom Dairy Services 8895 Guide Meridian Rd Lynden, WA 98264-9747 (360) 354-4344	Exact Scientific Services 3929 Spur Ridge Lane, Suite 1 Bellingham, WA 98226 (360) 733-1205
Manure	EC, OM, C:N, FC, total N, ammonia N~~um~~, nitrate, total P, pH	48 hours	Custom Dairy Services 8895 Guide Meridian Rd Lynden, WA 98264-9747 (360) 354-4344	Exact Scientific Services 3929 Spur Ridge Lane, Suite 1 Bellingham, WA 98226 (360) 733-1205
Forage	DM, CP (N), P, nitrate	72 hours	Custom Dairy Services 8895 Guide Meridian Rd Lynden, WA 98264-9747 (360) 354-4344	Edge Analytical, Inc. 805 West Orchard #4 Bellingham, WA 98225 (360) 715-1212

** See Table 7.2 for individual analytical methods for each analyte*

13.2. Corrective Actions

If problems with analysis at a laboratory arise, it will be foremost up to the lab manager to correct the issue appropriately. If not corrected, the samples will be sent to the secondary lab outlined in Table 13.1. If field equipment is not working, the sample will collected and sent to the laboratory listed for analysis.

Commented [NU25]: Also analysis of splits for NH3 and NO3? (i.e. 5% of field measurements sent for confirmation at lab – Section 14.2.2)

Commented [NU26]: The method they are using reports Ammonia-N

14. QUALITY CONTROL

In order to identify any variability in sample collection, analysis, or measurement activity, a quality control protocol will be in place. Variability will be tested for in-field (collection) and laboratory (analysis) procedures. A combination of blanks, repeated measures, and duplicates for all analytes and mediums measured will help measure the effect of errors and identify areas where corrective action should be taken.

The laboratories used in the study follow analytical method criteria and conduct their own in-house quality control procedures to ensure their methods and equipment are accurate and unbiased and that the data provided are of good quality. If at any time we feel that the primary laboratory is yielding questionable results, or we are having a quality issue with the lab, duplicate samples will be sent to the secondary lab for QC validation (see Table 13.1 for primary and secondary labs).

14.1. Blanks

Field blanks will be taken to assess the background or contamination levels (variability) of various parameters such as sample containers, handling procedures, and background pollution levels.

Field blanks will represent 2% of all samples (1 per 50 samples) taken for water quality parameters. A sample container will be filled with the same clean DI water used to rinse all equipment and bottles, handled in the same environment and the same way as sample containers and sent to the lab for analysis of the same analytes as the sample it is paired with.

A rinseate blank will be taken once every 50 samples for both soil and water samples. For soil samples, a rinseate will be taken for the soil probe by rinsing the probe with DI, collecting that water into a clean sample container and sending it in for analysis. For water samples, the YSI probe will be rinsed with DI water prior to use, collected directly into a sample container, and sent in for analysis. A positive value (above detection limits ± instrument error) will warrant more thorough cleaning procedures.

Field blanks for air quality measures will be taken to assess background (ambient) concentration and handling procedures. For ammonia, a period of ambient sampling at approximately 24 in above the soil surface will precede each sampling event. For greenhouse gases, a sample of ambient air will be taken at the same time as each sampling event.

14.2. Repeated (Replicate/Split) Measures

Repeated measures (replicate and/or split samples) will be conducted to assess the imprecision (random error) of in-situ field equipment and methods, sample collection and composite sampling methods, as well as to check the accuracy of laboratory analysis.

14.2.1. Replicate Samples

A replicate sample of surface water, soil water, soil, and manure will be taken every 20th sample (5% of total samples). The replicate will be taken immediately following the primary sample and sent to the lab for duplicate analysis. For soil and manure samples, the replicate will come from the same bucket as the primary sample, both of which are sub-samples from a composite of multiple samples.

14.2.2. Split Samples

A water sample will be split every 20th sample for assessment of handling and analyte variability. Each sample will be sent to the laboratory for analysis.

A water sample will be split every 20th sample for assessment of method/assessment variability. One half of the split sample will be sent to the laboratory for nitrate and ammonium analysis, and the other will be measured for nitrate and ammonium immediately with the field meter. This analysis will be used to compare the results of the field instrument to the laboratory results.

Commented [NU27]: Good!

Water samples measured in-situ with the field sampler will be split every 10th sample (10% of total samples) and both samples will be analyzed the same way with the field meter, cleaning the probe between samples. Values will be recorded in the field log book.

A difference of up to 30% will be accepted between samples (%Diff = (|sample 1 – sample 2|)/[(sample 1 + sample 2)/2] * 100%). If the samples differ by more than 30%, corrective action will be taken (see Table 14.1).

14.3. Accuracy (Precision & Bias)

Accuracy of field equipment will be assessed by in-field comparison to known values (i.e., known solutions, certified equipment values, etc.). (Note: this assessment will not be done in the field for gaseous ammonia as it is neither practical nor effective. Laboratory calibration, conducted annually by Pranalytica Inc., will verify the accuracy of the instrument).

To measure the in-situ precision of the YSI field monitor, temperature, nitrate, ammonium, and pH will be compared against known solutions or certified equipment every 10th sample. The pH probe will be verified with a known solution of pH 7.0. The nitrate and ammonium probes will be validated against a 1 mg/L calibration solution. Laboratory results of paired nitrate and ammonium samples taken in the field will be used to validate field probe accuracy. For temperature, a NIST certified thermometer will be inserted into the sample and compared against the instrument reading. Comparisons will be recorded in the field log book. Corrective action will be taken if any significant differences (Diff >10%) between the two methods are noted.

The temperature of the sample transport container (cooler) will be checked with a certified thermometer at each sample event. Temperature will be recorded in the field log book. Corrective action will be taken if the temperature is not at the specified level.

Table 14.1. Field sampling and analytical quality control parameters

Field QC	Analyte (Matrix)	Frequency	Acceptance Limits[1]	Corrective Action	Person(s) Responsible for CA	Data Quality Indicator (DQI)
Field Blanks	Surface Water	1 per 50 samples (2%)	No false negatives or positives	New containers, new sample water, resample, or qualify data	Field personnel (in-situ), Project Manager (lab)	Field and laboratory precision, bias, variability
	Soil Water	1 per 50 samples (2%)	No false negatives or positives	New containers, new sample water, resample, or qualify data	Field personnel (in-situ), Project Manager (lab)	Field and laboratory precision, bias, variability

	Ammonia	1 for each sample	No false negatives or positives	Subtract from sample value	Field personnel	Sample and background variability
	GHG	1 per sample event	No false negatives or positives	New syringes and/or exetainer; subtract from sample value	Field personnel	Field and laboratory precision, bias, variability
Rinseate	Water (All)	1 per 50 samples (2%)	Trace or lower detection	Clean YSI meter or soil probe	Field personnel	Bias, variability
Field Replicate (Duplicate)	Surface Water	1 per 20 samples (5%)	Within specified precision limits (RPD <30%)	Reclean, retest, SOP review, qualify data	Project Manager	Field and laboratory precision
	Soil Water	1 per 20 samples (5%)	Within specified precision limits (RPD <30%)	Reclean, retest, SOP review, qualify data	Project Manager	Field and laboratory precision
	Soil	1 per 20 samples (5%)	Within specified precision limits (RPD <30%)	Reclean, retest, SOP review, qualify data	Project Manager	Field and laboratory precision
	Manure	1 per 20 samples (5%)	Within specified precision limits (RPD <30%)	Reclean, retest, SOP review, qualify data	Project Manager	Field and laboratory precision
	GHG	1 per sample event	Within specified precision limits (RPD <30%)	SOP review, new syringes and vacutainers	Project Manager	Field and laboratory precision
Field Splits	Water (surface and soil)	1 per 10 samples (10%)	Within specified precision limits (RPD <30%)	Check monitor batteries, recalibrate field equipment	Field personnel	Equipment precision and accuracy
	Surface water	1 per 20 samples (5%)	Within specified precision limits (RPD <30%)	Recalibrate YSI meter; correct results if difference is consistent	Project Manager	Field YSI meter and laboratory variability; bias
Cooler Temp	Temp	Every sample event	Within specified range (2-6°C)	Adjust ice content of cooler (+/-)	Field personnel	Variability

[1]**RPD** = Relative percent difference.

14.4 Laboratory Quality Control Procedures

Sample analysis conducted by analytical laboratories will follow all approved methods (Table 7.2), SOPs, performance standards, and have reporting procedures in place according to approved (i.e., EPA or ~~DOE~~Ecology) protocols that meet project quality objectives. The laboratory performs their own in-house quality control and assurance checks on analytical equipment to ensure that the quality of their data is good as well as to identify and corrective action that needs to be taken in response to identified deficiencies. The internal QC checks may differ slightly for each individual procedure, but in general include the following (information obtained from Exact Scientific Services, Inc):

Method Blanks - performed at a frequency of one per batch of samples per matrix type per sample extraction or preparation test method. The results of these samples are used to determine batch acceptance.

Laboratory Control Sample (QC Check Sample) - are analyzed at a minimum of 1 per batch of 20 or fewer samples per matrix type per sample extraction or preparation method except for analytes for which spiking solutions are not available such as total suspended solids, total dissolved solids, total volatile solids, total solids, pH, color, odor, temperature, dissolved oxygen or turbidity. The results of these samples are used to determine batch acceptance.

Matrix Spikes (MS) - are performed at a frequency of one in 20 samples per matrix type per sample extraction or preparation method except for analytes for which spiking solutions are not available such as, total suspended solids, total dissolved solids, total volatile solids, total solids, pH, color, odor, temperature, dissolved oxygen or turbidity. The sample(s) selected for spiking are rotated among all received samples so that various matrix problems may be noted and/or addressed (sample chosen may not be related to this project). Poor performance in a matrix spike generally indicates a problem with the sample composition, and not the laboratory analysis, and is reported to assist in data assessment.

Surrogates - Surrogate compounds are added to all samples, standards, and blanks for all organic chromatography test methods except when the matrix precludes its use or when a surrogate is not available. Poor surrogate recovery generally indicates a problem with the sample composition and is reported to assist in data assessment.

Matrix Spike Duplicates (MSDs) or Laboratory Duplicates - are analyzed at a minimum of 1 in 20 samples per matrix type per sample extraction or preparation test method. The selected sample(s) are rotated among received samples so that various matrix problems may be noted and/or addressed. Poor performance in the duplicates generally indicates a problem with the sample composition and is reported to assist in data assessment.

15. INSTRUMENT/EQUIPMENT TESTING, INSPECTION, AND MAINTENANCE

Proper testing, inspection, and maintenance of equipment will help mitigate any equipment issues and keep it in proper working order, thus reducing field error and possible sampling failures. The following is an explanation of the testing, inspection, and maintenance procedures for project equipment. Table 15.1 summarizes all these actions.

15.1. Inspection and Testing of Equipment

Inspection and testing of equipment will be conducted on a regular basis to ensure proper functioning and accuracy. Corrective action will be taken as appropriate to the concern at hand.

All equipment, including the YSI Professional Plus meter, pH meter, Nitrolux-S ammonia analyzer, soil moisture meter, thermometer, and Kestrel weather station, will be inspected up to

72 hours prior to a sampling event. Gypsum blocks will be inspected once yearly (September) in the field. Inspection results will be recorded into a log book. Any corrective action will be taken as necessary.

15.2. Maintenance of Equipment

All equipment will be maintained as outlined by manufactures recommendations. When available, repair kits will be kept on hand so that equipment, probes, etc., can be repaired as quickly as possible to minimize down time.

Table 15.1. Equipment maintenance, testing, and inspection activity procedures

Equipment/ Instrument	Maintenance Activity	Testing Activity	Inspection Activity	Responsible Person	Freq.	Acceptance Criteria	Corrective Action
YSI Pro Plus Field Meter	Check cleanliness and batteries	Check batteries, test probes to standards, calibrate	Check DO membrane, and probe connections	Field Team Leader, Project Manager	Every sampling day	No debris on probes, battery >30%, each probe within specified resolution of standard	Change batteries, membrane, or clean probes as needed, calibrate, or send back to company
YSI pH Meter	Check cleanliness and batteries	Check batteries, calibrate	Check probe and connections	Field Team Leader, Project Manager	Every sampling day	Battery >30%, within 0.01 units of standard	Change batteries, clean probe, calibrate, or send back to company
Watermark Soil Moisture Meter	Check batteries	Check batteries, calibrate	Check readings	Field Team Leader, Project Manager	Every sampling day	Battery >30%, within resolution at saturation	Change batteries, send back to manufacturer
Gypsum Blocks	Check material % (lifespan), check leads	Check proper functioning of block	Dig up once yearly to inspect gypsum level	Field Team Leader, Project Manager	Every sampling day (leads), September (block)	More than 40% in tact	Replace block
NIST Thermo-meter	Check for cracks in shaft	Make sure it is reading	Check for cracks	Field Team Leader, Project Manager	Every sampling day	No cracks	If cracked, replace
Nitrolux-S Ammonia Analyzer	Clean, charge batteries	Run internal calibration	Check hoses, couplings, and ports	Field Team Leader, Project Manager	Every sampling day	Within internal calibration limits	Charge, clean, or send back to manufacturer
Kestrel 4000 Weather Station	Check batteries	Check battery life, calibrate sensors	Check station parts for cracks and tension	Field Team Leader, Project Manager	Every sampling period	Battery >30%	Change batteries, or send back to manufacturer

16. INSTRUMENT/EQUIPMENT CALIBRATION AND FREQUENCY

All field equipment will be calibrated on a regular basis and/or according to manufacture recommendations to ensure proper functioning and accuracy (Table 16.1). Equipment will be calibrated against known standards or NIST certified instruments. Calibration standards (pH 4, 7, & 10; nitrate 1 & 100 mg/L; ammonium 1 & 100 mg/L) will be kept on hand to ensure timely calibration procedures are followed. All calibration will be done by trained personnel following standard procedures and recorded in a log book. The project manager will periodically check all calibration documentation to ensure it is being done on schedule and that any identified errors have been noted and addressed.

16.1. Field Calibration

Field equipment will be calibrated prior to going out into the field for sampling events (see Table 16.1.). If any of the field equipment fails a field QC check, field equipment will be recalibrated and measures will be run again.

16.2. Calibration Standards

Certified NIST calibration standards and instruments will be used for calibration of field equipment. Certified calibration standards (pH, nitrate, conductivity, nitrate, and ammonium) will be purchased from the same company supplying the field monitor (YSI). Equipment will be calibrated on a one, two or three point scale. In-field spot checks will be done with a one point calibration. Comprehensive calibration checks will be done with a three point calibration (2 for pH) for more accurate calibration.

An NIST certified thermometer will be used to calibrate temperature readings from the field meter and weather station, as well as measure the transport cooler temperature.

Table 16.1. Equipment and instrument calibration procedures

Equipment/ Instrument	Probe/Model	Procedure	Frequency of Calibration	Acceptance Criteria	Corrective Action	Person Responsible
YSI Professional Plus Meter	**DO**	2 to 3 point calibration to known standards	Before every sampling event	0.01 mg/L	Clean, recalibrate, or send back to manufacturer	Field Team Leader, Project Manager
	Temperature	Calibrate to NIST certified thermometer	Twice per year	0.1 °C	Clean, recalibrate, or send back to manufacturer	Field Team Leader, Project Manager
	Conductivity	1 point calibration to known standards	Before every sampling event	0.001 or 0.1 mS/cm	Clean, recalibrate, or send back to manufacturer	Field Team Leader, Project Manager
	Ammonium	2 point calibration to known standards	Before every sampling event	0.01 mg/L-N	Clean, recalibrate, or send back to manufacturer	Field Team Leader, Project Manager

	Nitrate	2 point calibration to known standards	Before every sampling event	0.01 mg/L-N	Clean, recalibrate, or send back to manufacturer	Field Team Leader, Project Manager
YSI pH Meter	**YSI pH10 Meter**	3 point calibration to known standards	Before every sampling event	0.1 units	Clean, recalibrate, or replace pH sensor	Field Team Leader, Project Manager
Soil Moisture Meter	**Watermark**	Calibrate to 0 and 100% saturation	Every 4 months (Jan, Apr, July, Oct)	Within 10% error	Recalibrate, check leads, send back to manufacturer	Field Team Leader, Project Manager
Gypsum Blocks	**Watermark**	Calibrate to 0 and 100% saturation	Before installation	Within 5% error	Replace	Field Team Leader, Project Manager
Ammonia Analyzer	**Nitrolux-S**	Manufacture calibration	Once per year	NA	NA	Project Manager, Manufacturer
Weather Station	**Kestral 4000**	Calibrate RH to standards, & temperature to NIST thermo.	Every 4 months (Jan, Apr, July, Oct)	Within 5% error	Recalibrate, send back to manufacturer	Field Team Leader, Project Manager

16.3. Laboratory Calibration

The laboratories used perform their own calibration procedures according to the requirements specified in the analytical method and in the labortory's SOP at set frequencies (SOP available upon request of laboratory). As it relates to the primary laboratory used in the study, Exact Scientific Services, wherever applicable, calibration of support equipment and instruments are traceable to national standards of measurement. Prior to use on each working day, balances, ovens, refrigerators, freezers, incubators and water baths are checked with NIST traceable references (where possible) in the expected use range. Calibration procedures for a specific laboratory instrument will consist of an initial calibration, and calibration verification, when an initial instrument calibration is not performed on the day of analysis. The SOP for each analysis performed in the laboratory describes the calibration procedures, their frequency, acceptance criteria and the conditions that will require recalibration. In all cases, the initial calibration is verified using an independently prepared calibration verification solution. Reference standards of measurement (such as Class S or equivalent weights or traceable thermometers) are used for calibration only. Reference standards are subjected to in-service checks between calibrations and verifications. Each calibration is dated and labeled with or traceable to the method, instrument, analysis date, and each analyte name, concentration and response (or response factor). Sufficient information is recorded to permit reconstruction of the calibration. Acceptance criteria for calibrations comply with method requirements or are established and documented. All calibrations are dated and recorded for each instrument and are available for review upon request.

17. INSPECTION/ACCEPTANCE OF SUPPLIES AND CONSUMABLES

Most of the supplies and consumables utilized by the project are not "critical" for the project. The supplies that are critical to the project are all sample containers, calibration standards, and wash water.

To ensure that sample containers are sterile and of appropriate material for collection and analysis, all sample containers will be supplied by the analyzing laboratory. Calibration standards will be purchased from a company that can certify the reference standards that will be used for calibrating field equipment. In this case, we will purchase standards (pH, nitrate, conductivity, and ammonium) manufactured at North Central Labs (Birnamwood, WI). Wash water will be deionized (DI) water purchased in sealed gallon jugs. All of these supplies will be kept on hand and repurchased before they get low. When available, certificates and testing records will be kept by the Project Manager.

All supplies will be checked for acceptable parameters so that they meet project needs and capabilities. Supplies that do not met project needs, or are damaged, will be returned and an alternative found.

All project supplies and consumables will be checked by the Project Manager on a monthly basis to ensure appropriate quantities are always on hand. A detailed list of products, supplier (vendor), and minimum quantity to be kept on hand will be compiled and checked on a monthly basis. All supplies will be stored on site at WCD.

18. NON-DIRECT MEASUREMENTS

Current and historical data on various water quality standards (fecal coliform, DO, temperature, conductivity, turbidity, and salinity) measured at specific sites within the watersheds (information available upon request) will be utilized by the project for identifying trends, areas of concern, and locations to target mitigation within the watersheds. The water quality data is provided monthly or bi-monthly by ~~DOE~~Ecology and WIRA 1. All sample attainment, measurements and analysis are conducted by the Northwest Indian College (NWIC). Quality assurance plan and SOP are available from NWIC. The NWIC SOP and analytical method for fecal coliform sampling is comparable to the one used by this project, therefore, a comparison of measures can be conducted.

Commented [NU28]: Please clarify the role/sampling NWIC is doing for the project. Let's discuss!

To establish background values for risk estimates, scientific values from peer reviewed literature articles may be utilized. Any values used will be checked for validity and referenced appropriately.

Meteorological data from weather stations listed in Table 10.2 will be recorded and utilized to compare against our measured field data, as well as utilized by the ARM worksheet to forecast precipitation events. Trends in predicted and actual precipitation events will be recorded and analyzed for correlation for predictive and weighted (accuracy) purposes. Correlations between measures will be analyzed to determine which sites are most accurate and appropriate to utilize for certain areas throughout the County.

19. DATA MANAGEMENT

The proper management of data throughout the project lifecycle is crucial to the success of the project. This section details the data management process for data recording (logbook and instrument logger), verification and validation, transmittal, analysis, database transfer, management, and storage.

19.1. Data Collection, Entry, and Storage

Two types of data will be produced in the field, written data and logged data. All quantitative written data collected in the field (pH, soil temperature, soil moisture, thermometer temperature, QC checks, notes) will be recorded in a bound notebook following guidelines in section 12. This data will then be entered into the appropriate Excel spreadsheet within one week of the sampling event. Data logged by field equipment (multi-meter, ammonia analyzer, meteorological, GPS) will be downloaded using the appropriate technology and transferred to Excel within one week of data collection. Even though field equipment is able to log data, secondary written notes will be taken as a backup measure. All data will be checked by the project manager for error, outliers, or other abnormalities. Where appropriate, qualitative data (notes) recoded in the field will be entered into the appropriate spreadsheet. More often, this information will be used to assess abnormal data, trends, and relationships.

All analytical results obtained from the laboratories for field samples (water, soil, manure, forage, air), will be entered into the appropriate spreadsheet upon receipt from the laboratory. A hardcopy of all results will be retained by the Project Manager in a single binder. The lab also retains copies of all lab results in an online database which can be accessed by the Project Manager at any time.

All data will be managed by the Project Manager and/or the Data Manager. The data manager will store the data on WCD's secure server. Monthly backups and/or hardcopies of all data files will be kept in a secure off-site location in case of damage to the server. Per EPAs request, appropriate data will be transferred and stored on STORET by the Data Manager. Per EPA: "STORET (short for STOrage and RETrieval) Data Warehouse is an online repository for water quality, biological, and physical data and is used by state environmental agencies, EPA and other federal agencies, universities, private citizens, and others".

19.2. Data Control and Verification

All data recorded and transferred to Excel or any other storage program is subject to quality control. Data sets will be verified by a second pair of eyes to ensure they are entered correctly.

Once all data is entered into Excel, it will be statistically analyzed in Excel for number, ranges, means, medians, standard deviations, and minimum and maximum values, as well as in SAS (SAS Institute., Cary, NC) using the appropriate statistical model. If appropriate, outliers will be identified and corrective action taken, if necessary, specific data sets will be transformed based on distribution and regression relationships, or other appropriate data processing tasks will be conducted. Comparison of data sets from each sample trial will be conducted on a temporal and spatial scale within and between test farms. Once appropriately analyzed and verified, data will be complied and reported.

20. ASSESSMENTS AND RESPONSE ACTIONS

Regular assessment of project activities, deliverables, and tools will be conducted to ensure that timelines are followed and outcomes achieved (see Table 20.1).

20.1. Assessment of Project Activities

All project activities will be audited on a monthly basis by the Project Manager to make sure that proper protocols are being followed for sample collection, handling, documentation, sample chain-of-custody, equipment checks and calibrations, and reporting. A quarterly review of all calibration records, field logs, laboratory results, and other documentation records will be conducted for completeness. Corrective action and follow up audits will be conducted if and when necessary.

20.2. Data Quality Assessments

Assessments of data quality will be conducted throughout the project by the Project Manager. Quality will be assessed based on results from calibrations, QA samples and tests, field documentation, statistical assessment (see 19.2.), and data review. Any areas of poor quality, based on set criteria, will be evaluated and corrected.

20.3. Project Deliverables

Project timelines will be reviewed on a monthly basis to make sure goals and deliverables are being met. If any severe deficits in time or activities are noted, corrective action will be taken, including reevaluation of project timelines, more project management or oversight, delegation of tasks, or restructuring of personal schedules. It is anticipated that QAPP addendums and updates will be made on a yearly basis based on project data collection and/or revision of methods.

20.4. Response Actions

The response action taken for correction of any project issues will be the responsibility of the Project Manager and/or the Project Oversight position. If corrective action is outside of the roles of WCD personnel, the EPA project office will be consulted.

Table 20.1. Project assessment activities, frequency, and responsible party

Assessment Type	Frequency	Person Performing Assessment	Person Monitoring Corrective Action
Field Sampling	Monthly	Project Manager	Project Manager
Analytical Data	Monthly	Project Manager	Project Manager
Laboratory Procedures	Per laboratory	Laboratory Manager	Laboratory Manager
Data Quality	Quarterly	Project Manager	Project Manager
Data Storage	Bi-annual	Data Manager	Project Manager
Project timelines and deliverables	Monthly	Project Manager	Project Manager
Records	Quarterly	Project Manager	Project Manager

21. REPORTS TO MANAGEMENT

Reporting is a necessary part of the project in order to assess progress and keep the granting agency (EPA) informed of project activities. Both quarterly financial and bi-annual project reports will be compiled and sent to the granting agency starting in 2010. Project reports, prepared by the Project Manager, are due at the beginning of January and July, and the final project report is due June 30, 2014. Included in progress reports will be a summary of data quality and quality assurance activities, corrective action taken for any significant project activity, and the project status as related to activity timelines.

22. DATA REVIEW, VERIFICATION, VALIDATION

This section lists the criteria for data review, verification, and validation to ensure that project data is of good quality.

22.1. Data Review

Data review is the process by which all data is reviewed by project personnel (Field or Project Manager) to ensure that data have been recorded, transmitted, and processed correctly. All data and notes collected in the field will be reviewed for completeness and accuracy by the Project Manager on a regular basis following each sampling event. Sample results received from the laboratory will also be reviewed for discrepancies. All calibration and QA samples will be assessed to make sure they have been conducted according to schedule and that there are no significant results that were not properly corrected.

All data transmitted to Excel will be reviewed for accuracy by the Project Manager after each entry event. All calculations or transformations conducted within Excel will be reviewed by the Project Manager.

In addition to data, experimental design and sample number review will be conducted after year one to see if modifications or more stringent sampling protocols need to be added. Any revisions will be written up and a new QAPP will be submitted for review and approval.

22.2. Data Verification

Data verification is the process by which data is evaluated for completeness, correctness, and conformance. Following data review to ensure data have been entered correctly, data will undergo a verification process whereby outliers, missing data, or incomplete data will be identified and corrected as appropriate.

22.3. Data Validation

Data validation is the process by which the quality of a specific data set is determined relative to its end use. If any data set deviates from the QAPP, the Project Manager, project QA person, and EPA QA person will be consulted for validity and corrective action of the data set.

23. VERIFICATION AND VALIDATION METHODS

Data verification and validation will be performed by review of data completeness, calibration results, QA sample results, chain-of-custody forms, and statistical analysis. Verification will be conducted on data recording and transfer, data calculations, transformations, sorting, assessment of outliers, and qualification of data. Many of the procedures for conducting these reviews have been covered throughout this plan.

Data entry and verification will be conducted by the field personnel, Field Manager, Project Manager, or Data Manager. The Project Manager will review all data verification and validation reports to see if there have been any errors or deviations from the QAPP. The Project Manager will report to the Project or EPA QA Officer if corrective action needs to be taken.

24. RECONCILIATION WITH USER REQUIREMENTS

This section of the plan describes how the validated data will be evaluated to see if it meets project quality objectives (measurement and data quality). Under a systematic planning approach, EPA recommends that projects use the five Data Quality Assessment (DQA) process steps to evaluate how well the validated data supports the intended use. Those five steps are outlined below.

24.1. Review the Data Quality Objectives and Sampling Design

The data quality objectives (DQO) outlined in Section 7 will be reviewed on an annual basis by the Project Manager to assure that they are still applicable. Any revision to DQOs will be made by the Project Manager, be consistent with QAPP objectives, and be documented in an approved QAPP addendum. Similarly, sampling designs will be assessed after an adequate amount of data has been collected to assess variability of data and sample number estimations. Sample design revisions, although not expected, will be made when appropriate to best meet the needs of the project objectives while minimizing error. All changes will be documented in and approved QAPP addendum.

24.2. Conduct a Preliminary Data Review

A preliminary data review will be conducted quarterly after each seasonal data collection period. Preliminary data review will consist of basic statistical analysis to identify normality, bias, outliers, anomalies, correlations, relationships, patterns, and insufficient data sets. This data review will aid in refining data collection techniques, modifying sample numbers, identifying relationships, and teasing out data set transformation when necessary.

If it is determined that a data set is below the acceptable sample variability (CV < 10%), sample frequency may be assessed to see if resources can be refocused to areas of the study that may require more frequent sampling to achieve the desired CV.

24.3. Select the Statistical Test

The statistical tests used for identifying relationships between and within data sets, as well as significant and error may vary for each analyte and variable. Choosing a statistical test will be based on the variability and distribution of the data, as well as the acceptable error and objective of the data set. Overall, all data sets will be analyzed for significance at an alpha of 0.05.

24.4. Verify the Assumptions of the Statistical Test

Verification of the assumptions of the statistical test chosen will assess whether the underlying assumptions are valid or whether departures from the test are acceptable. This assumption will be based on the amount of data available and may vary over time after more data has accumulated.

24.5. Draw Conclusions from the Data

After data has been reviewed and verified, it will be analyzed using the appropriate statistical test identified in step 3. Once analyzed, conclusions will be drawn and presented. Data will be presented in text, tables, and figures as appropriate for the data set and relationships being assessed. Conclusions should support project objectives and hypothesis testing.

If limitations of a data set (i.e., missing data, unusable data, etc.) are discovered during analysis, it will be reported as such. If data quality indicators do not meet performance criteria, sample design or analysis will be adjusted when possible. All adjustments made by the Project Manager will be verified with QA Managers.

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